ONTARIO ENERGY REVIEW

4th Edition

Energy leadership

For economic strength

Ontario
Ministry
of
Energy

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March 1990

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Foreword

I am pleased to introduce the fourth edition of the Ontario Energy Review. This edition provides a factual review of the developments in Ontario in relation to the national and international energy scene.

Ontario is the largest energy consumer in Canada, and it is highly dependent on external energy sources. As a result, we in Ontario are not isolated from Canadian and international energy developments.

Since the last edition of the Ontario Energy Review, several developments have significantly altered the Ontario energy scene. We have moved from an era of regulated oil and gas markets to one of deregulation, where market forces increasingly determine prices. Meanwhile, a comprehensive Free Trade Agreement with the United States has come into effect, making us even more affected by international markets. Oil and gas prices have fallen from the high levels of the early 1980s. But, energy efficiency and conservation continue to be extremely important to our province, because they directly improve our economic performance, as well as our environment.

In the next few years our greatest challenges will be to continue improving our energy efficiency, to reduce the impact of energy on the environment, and to ensure sufficient energy supplies are available for future needs.

By understanding the developments of the recent years we can comprehend our current energy situation and plan for the challenges we will face in the years ahead.

The Ontario Energy Review contains the recent statistics on energy in Ontario and explains them for the non-specialist in the field. I hope that it will help the public gain a greater awareness of energy matters in our province.

Lyn McLeod

Hon. Lyn McLeod
Minister of Energy
November, 1989

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Energy in Ontario and Canada

Canada is a net exporter of energy and uses energy itself more intensively than other countries, though energy efficiency has increased dramatically. Ontario accounts for one-third of Canada's energy consumption and purchases most of the energy it uses from the western provinces.

How energy is consumed in Ontario

Ontario has a modern industrial economy that consumes all the major types of energy. The leading energy source in 1988 was crude oil, which accounted for 29 per cent of all primary energy consumed. Natural gas and associated liquid fuels were next in importance (24 per cent), followed by nuclear fission (20 per cent), coal combustion (15 per cent), and hydro-electricity (10 per cent). Wood waste burned for energy by the forest products industry and wood used for home heating provided the remaining 2 per cent. This primary energy is converted and delivered by the energy industries into end-use forms for consumption.

Energy: A Few Definitions

Some traditional energy sources are freely available for direct use, such as sunlight for agriculture and wind for sailing vessels. But industrialized societies like Ontario depend mainly on manufactured and distributed "secondary" energy forms to operate furnaces, car engines, electric motors, lights, industrial boilers, and so on. The four main forms of secondary energy are petroleum products (the derivatives of crude oil, such as gasoline), natural gas, electricity, and coal products.

The job of the energy industries is to retrieve the naturally available "primary" energy sources, convert them into consumer-usable secondary energy forms, and deliver the latter to customers. These activities, such as refining crude oil, generating and transmitting electricity, and pipelining natural gas, themselves consume energy. Therefore, to supply consumers with a given amount of secondary energy requires a somewhat larger amount of primary energy.

Primary energy sources are also converted into certain industrial raw materials. For example, crude oil is used to make petrochemicals, lubricating oils, waxes, and asphalt. When these non-energy uses are added to the secondary energy outputs, the result is total "end-use energy". Total consumption of end-use energy plus energy used by energy industries gives total primary energy consumption.

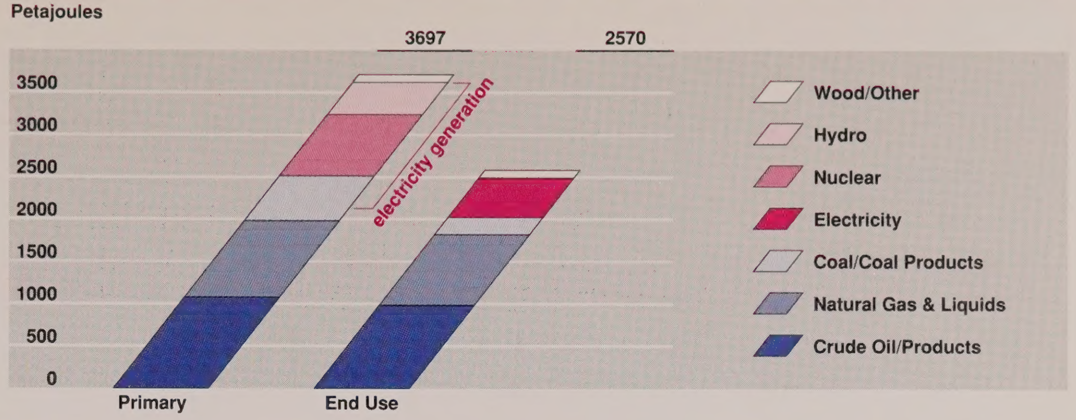
Most of the energy absorbed by the energy industries occurs in electricity generation. This is the energy consumed in manufacturing electricity. In Ontario the typical coal-burning power plant produces about one-third as much electrical energy as it consumes as primary energy in coal. By convention the same loss of about two-thirds of primary energy through conversion inefficiency is also attributed to hydro-electric and nuclear generation.

Among economic sectors the largest consumer of energy in Ontario is industry, which uses 36 per cent of total end-use energy. Transportation is next in importance (24 per cent), followed by the residential sector (19 per cent) and the commercial/institutional sector (13 per cent). Non-energy uses in the manufacture of petrochemicals, asphalt, lubricants, waxes, and so on account for the remaining 8 per cent.

These sectors vary in their use of the various forms of energy. For instance, whereas oil products provide almost all the energy for transportation (98 per cent), they provide only 10 per cent of the energy used in industry. Natural gas is the mainstay of the residential (53 per cent) and commercial/institutional (46 per cent) sectors. Apart from its contribution to electricity generation, coal is used only in the industrial sector, mostly in the iron and steel industry.

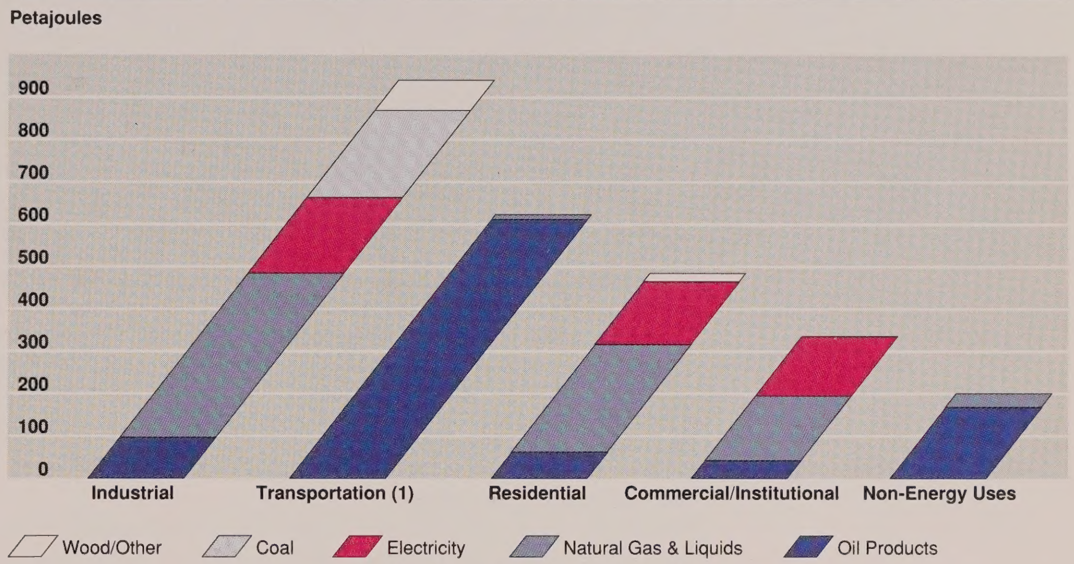
ENERGY CONSUMED IN ONTARIO IN 1988

Oil, natural gas and electricity are the main forms of energy consumed in Ontario.



END-USE ENERGY CONSUMPTION IN ONTARIO, 1988

Fuel dependencies differ between economic sectors.



(1) includes 1.3 petajoules of electricity

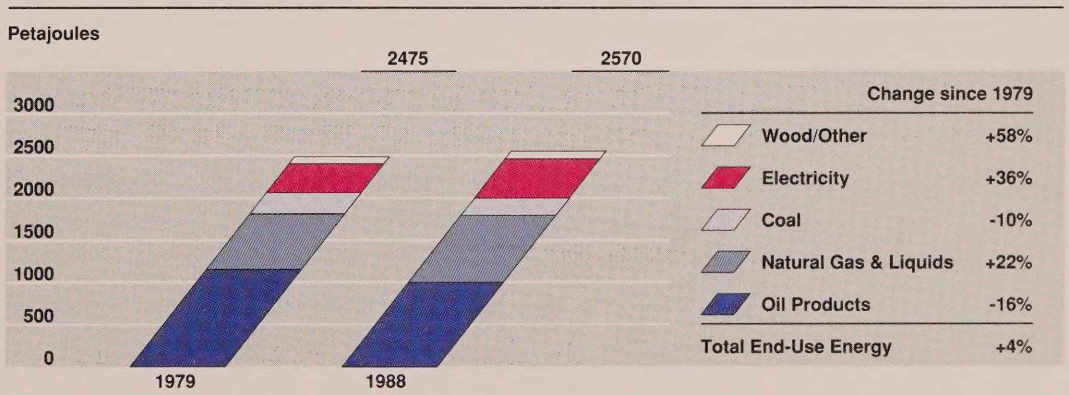
Energy efficiency has improved greatly

Until the late 1970s, energy use in Ontario tended to grow at about the same rate as the economy. But the year 1979 saw the beginning of a dramatic slowdown in energy growth. From 1979 to 1988, while the Ontario economy grew by 39 per cent, total end-use energy consumption grew only one-tenth as much (4 per cent).

The slowdown in consumption growth was greatest from 1979 to 1985, when oil, natural gas, and coal prices reached unprecedented levels and the economy suffered a severe recession. Since 1986, lower oil and natural gas prices have stimulated energy consumption, but it continues to grow more slowly than the economy.

CHANGES IN ONTARIO'S END-USE ENERGY CONSUMPTION, 1979-1988

In the last decade natural gas and electricity have displaced oil products, but total energy consumption has grown very little.

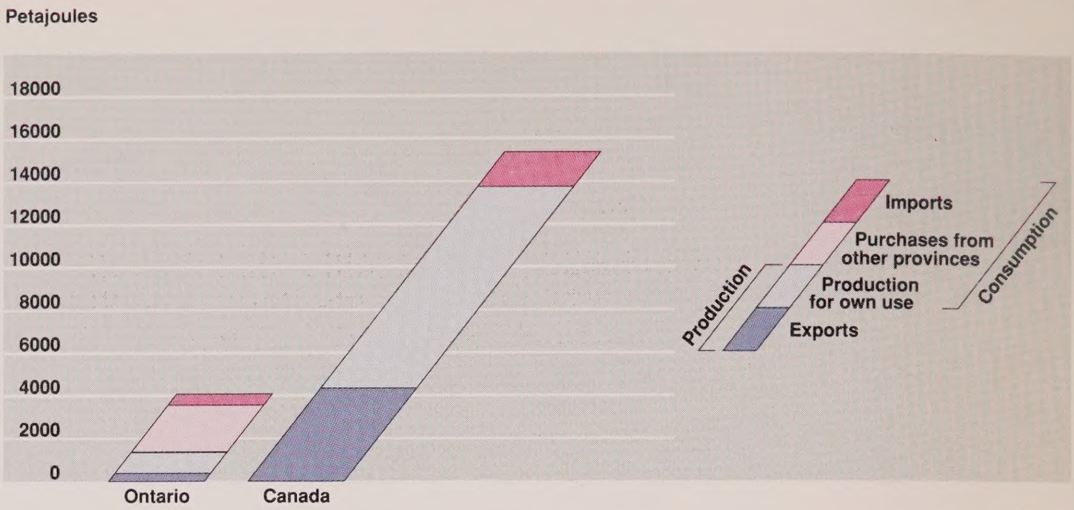


Trade and self-sufficiency

Though Canada produces all the main primary energy sources in abundance, Ontario produces very little crude oil, natural gas, or coal. Not surprisingly, therefore, Canada exports energy, while Ontario purchases energy – mainly from western provinces but also from the United States.

ONTARIO AND CANADA: PRIMARY ENERGY PRODUCTION, CONSUMPTION, AND TRADE, 1988

Ontario buys most of the energy it needs, while Canada has a surplus to sell.



The principal sources of energy within Ontario are water-power and uranium for electricity production. (Although 30 per cent of the uranium for nuclear stations now comes from Saskatchewan). The remainder of Ontario's primary energy is wood and waste used by the forest industries, and small amounts of crude oil and natural gas produced in southwest Ontario.

As in 1970, Ontario still relies on outside supplies for most of its primary energy, in particular for almost all the crude oil, natural gas, and coal. However, from 1970 to 1988 the Ontario content of primary energy consumption increased from 20 per cent to 26 per cent, as electricity from nuclear generation expanded.

In 1988, 61 per cent of Ontario's primary energy came from other provinces, chiefly Alberta (47 per cent) and Saskatchewan (12 per cent). Crude oil purchases from Alberta are lower than a decade ago, but purchases of uranium, lignite coal, and natural gas from Saskatchewan have increased. An additional 13 per cent came from the U.S., mainly American coal for Ontario steel plants and coal-fired power stations.

Comparisons of energy use

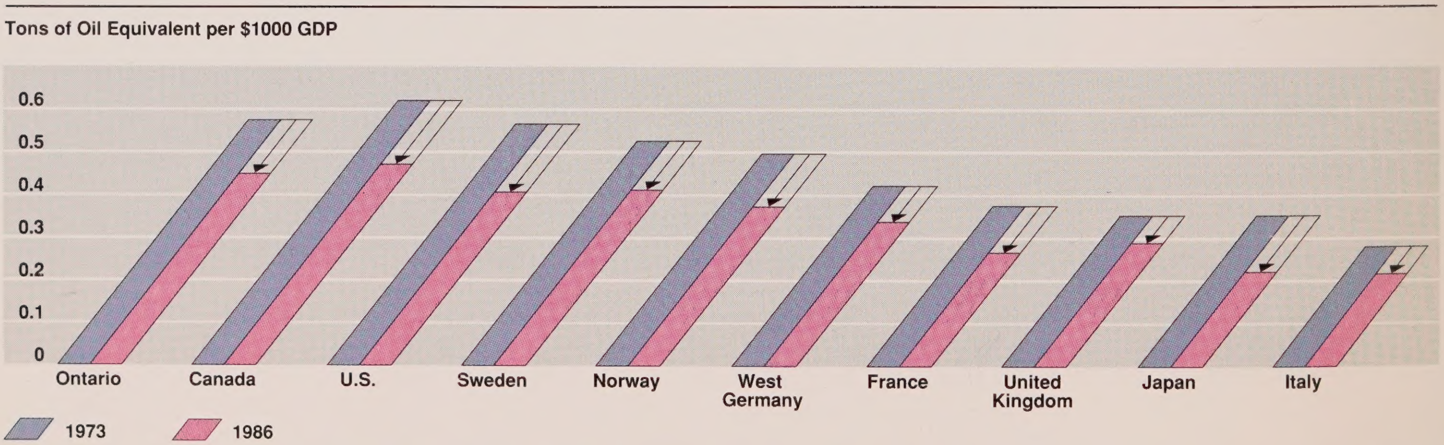
Canada uses a lot of energy for its population and the size of its economy. Canada uses more energy per dollar of output than any other major industrialized country, and Ontario's level of energy use is 96 per cent that of Canada. In comparison, the United States' level is 86 per cent of Canada's, Sweden's 87 per cent, West Germany's 72 per cent, France's 56 per cent, and Japan's 47 per cent.

One reason is that Canada's economy includes more than its share of resource industries that are heavy energy users. Canada has only 4 per cent of the total economic output of the Organization for Economic Co-operation and Development (OECD) but accounted for 40 per cent of newsprint production, 33 per cent of aluminum production, 30 per cent of nickel production, 17 per cent of iron ore production, and nearly 10 per cent of OECD production of copper, zinc, lead, and synthetic ammonia (in 1983).

Compared to Canada as a whole, Ontario has 36 per cent of the population and 41 per cent of the national Gross Domestic Product. Ontario's primary energy use, at 34 per cent of the Canadian total, is nearly proportional to population but significantly lower than its share of economic output.

ENERGY CONSUMPTION PER THOUSAND DOLLAR OF OUTPUT FOR ONTARIO, CANADA, AND SELECTED COUNTRIES, 1973 vs 1986

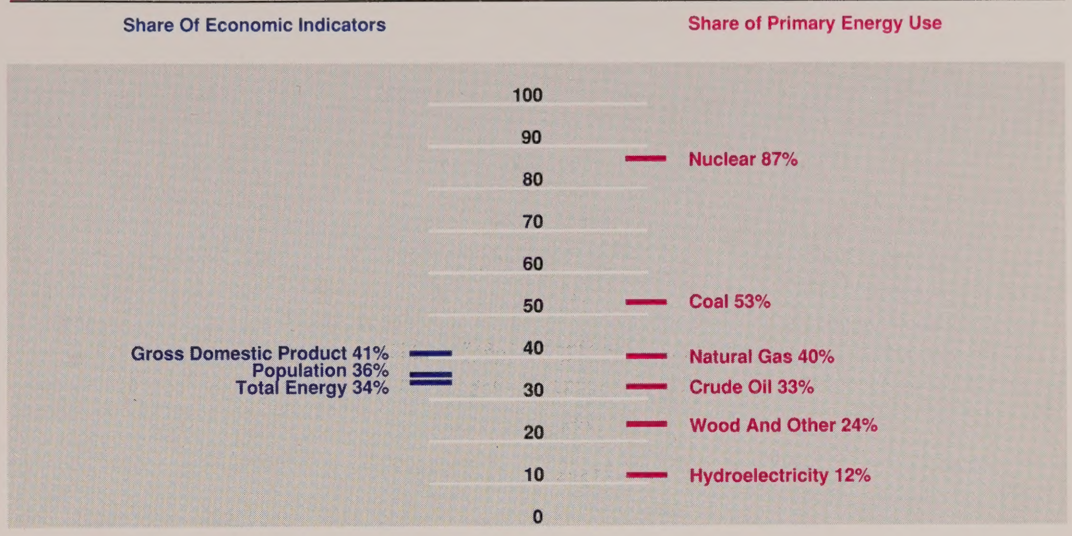
Ontario and Canada use more energy for their economic output than other developed countries, although all have improved their energy efficiency.



The provinces differ substantially in their patterns of energy use, depending on availability of resources and type of industry. Ontario accounts for approximately its share of national consumption of crude oil (33 per cent) and natural gas (40 per cent), somewhat more coal (53 per cent), and somewhat less wood and other sources (24 per cent). The main differences are that Ontario uses far more nuclear power (87 per cent of the national total) and far less hydro-electric power (12 per cent) than the nation as a whole.

ONTARIO'S SHARE OF CANADIAN PRIMARY ENERGY USE IN 1987

Ontario uses less hydroelectricity and more nuclear energy than the national average.



Oil

AROUND THE WORLD

Oil prices have dropped, demand is increasing but is still below its 1979 peak, and new supplies continue to be developed. Estimated OPEC reserves have increased substantially, particularly in the Middle East.

Crude oil is the world's most important energy source:

- **it accounts for nearly two-fifths of global primary energy use, more than any other source**
- **as the source of virtually all liquid fuels it is the basis of transportation worldwide**
- **it is traded internationally to a much greater extent than other energy sources**
- **its price strongly influences all energy prices.**

Therefore, what happens to oil around the world is important to Ontario energy consumers.

IN CANADA

Lower demand has made Canada a net exporter of oil again, but the price collapse has caused contraction in the oil industry and slowed development of new supply.

IN ONTARIO

More efficient consumption patterns and the substitution of other fuels have reduced the demand for oil, even with strong economic recovery. Current concerns include the need for substantial refinery investments to meet environmental standards (both for the refinery and for products) and the possible future need for alternative supply routes.

AROUND THE WORLD

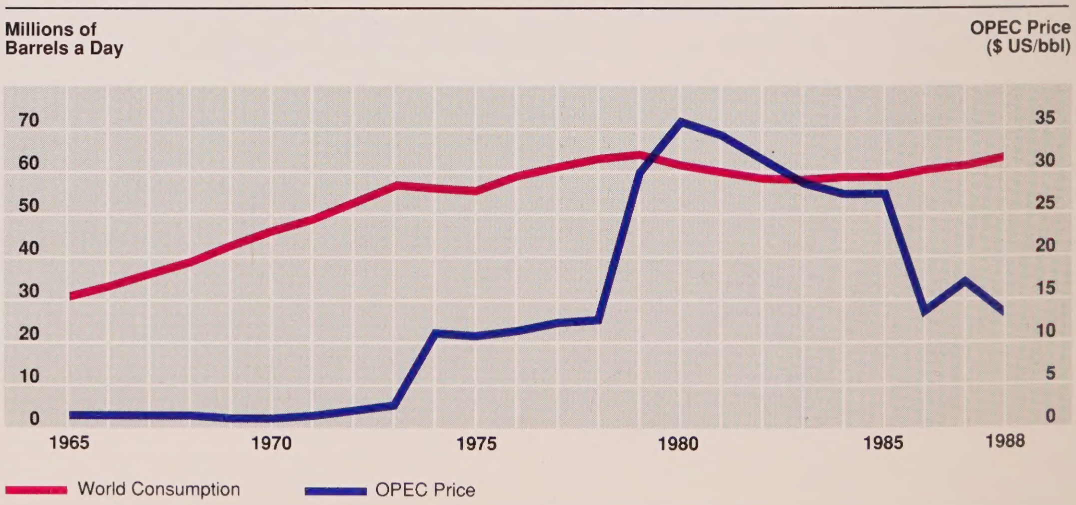
Lower prices

In 1986 world oil prices fell sharply from the high levels sustained from 1979 through the early 1980s. Within the first few months of 1986 the price of oil fell from $28(US) a barrel to as low as $10. Since then it has fluctuated. In the spring of 1989 the average price of Saudi light crude was around $18. The stage had been set for this price decline by the consequences of the oil price rises of the 1970s:

- lower demand due to improved energy efficiency
- increased supply from previously unprofitable sources
- consumer shifts to other sources of energy, such as natural gas, coal, and electricity
- world recession, which undercut industrial oil consumption.

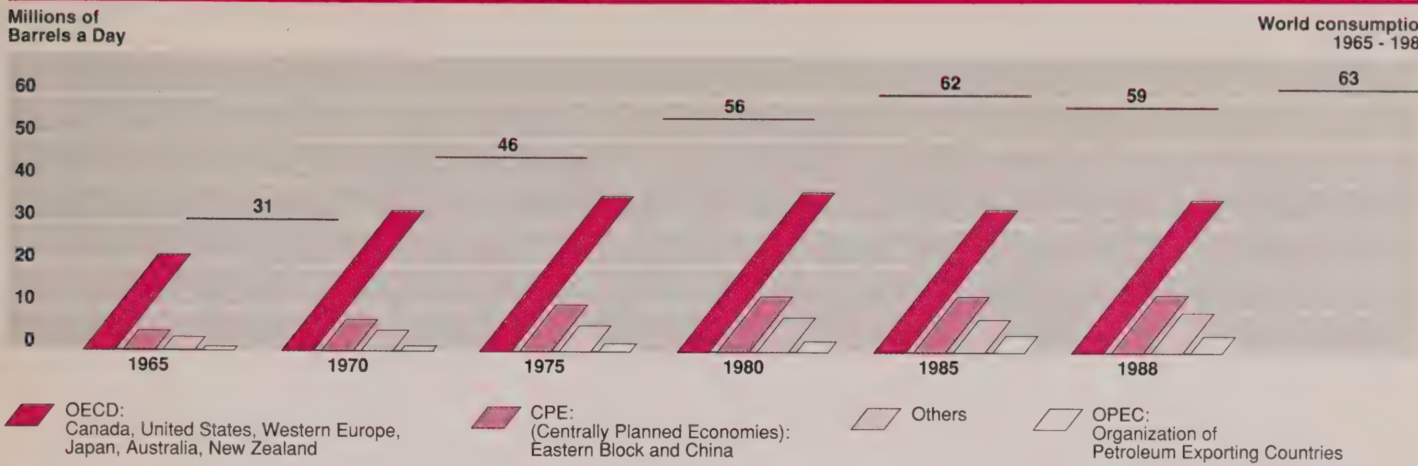
Reduced demand

In 1988, just over 63 million barrels (10 million cubic metres (m^3)) of oil was consumed daily, worldwide. About one-half of this total was consumed in the OECD countries, while centrally planned economies (CPEs) consumed just over one-fifth of this total. The U.S. alone was responsible for one-quarter of the world oil consumption in 1988.



WORLD OIL PRICES AND CONSUMPTION, 1965-88

Rising oil prices pulled down consumption growth, which has begun to respond again to falling prices.



OIL CONSUMPTION BY REGION, 1965-88

OECD countries remain the dominant consumers, though other blocks are growing slowly in importance.

OIL PRODUCTION BY MAJOR GROUPS, 1965-88

OPEC's dominance of world production has been undermined since the mid-1970s.

World oil consumption peaked at just above 64 million barrels (10 million m^3) a day in 1979, and then declined by nearly 10 per cent over the next four years. The fall in consumption worldwide was especially sharp in the developed OECD countries. Much of the decline occurred in the use of fuel oil in industrial boilers, power plants and heating for homes and buildings, but demand for gasoline, diesel fuel and other oil products also fell.

Oil consumption began to grow again after 1983 but has not yet regained its 1979 level. World oil consumption grew by 1.4 per cent in 1987 and 3.1 per cent in 1988, but at 63 million barrels a day it was still about 1.5 per cent below the 1979 peak.

OPEC remains at centre stage

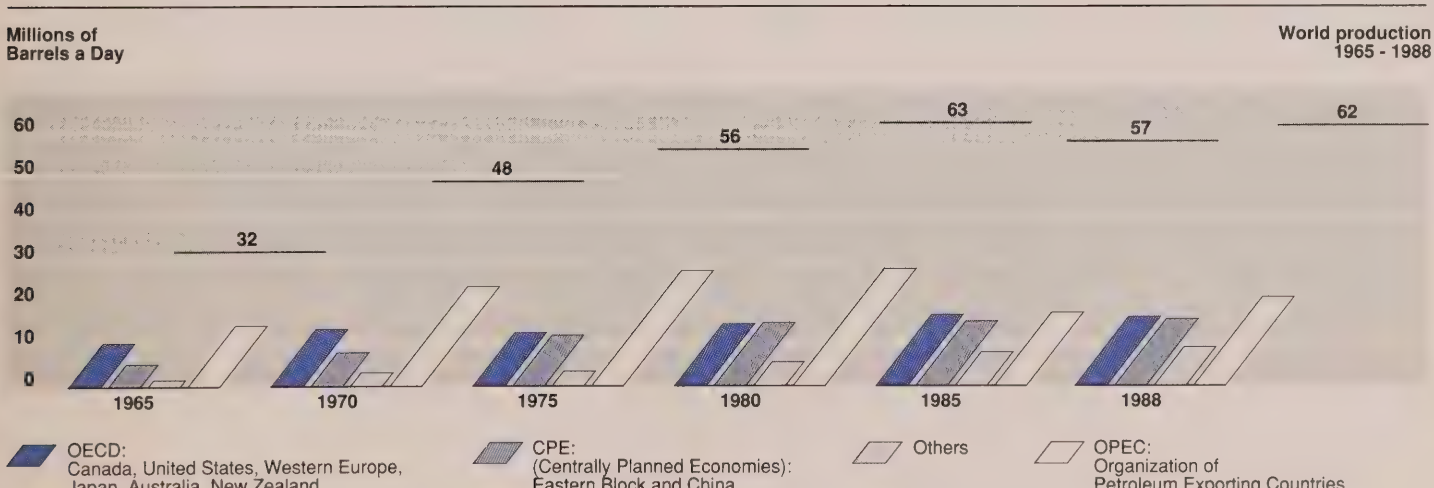
In 1988, world oil production reached 62 million barrels (10 million m^3) a day, 4 per cent more than 1987. The Organization of Oil Exporting Countries (OPEC) produced 34 per cent, non-OPEC producers (countries such as the U.S., UK, Norway, Mexico, Canada, etc.) accounted for 40 per cent, and the remaining 26 per cent was produced by the CPEs. The USSR was the single largest oil producing country in the world in 1988, followed by the U.S., Saudi Arabia and Mexico.

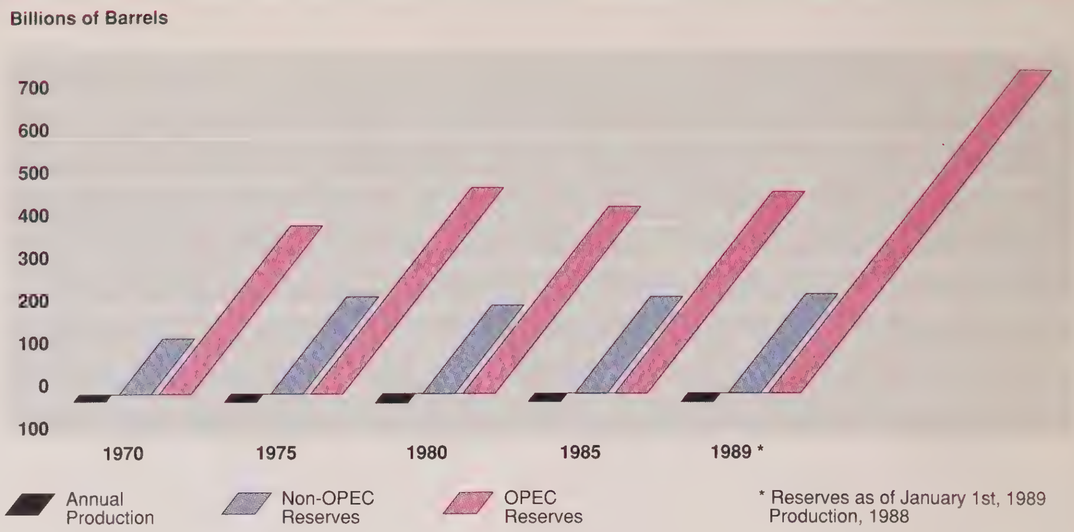
Since the early 1980s the OPEC nations, led by Saudi Arabia, have shouldered the burden of reducing supply to match declining world oil demand. Between 1979 and 1988, OPEC oil production plunged by more than one-third from 31 million to 20 million barrels (5 million to 3 million m^3) a day. Yet production in non-OPEC countries actually grew by about 7 million barrels (more than 1 million m^3) a day as new fields in places such as Alaska and the North Sea came on stream.

With the flexibility made possible by its huge, low-cost production capacity, OPEC has been able to act as the world's "swing supplier" of oil, pumping whatever volume the market requires after all other producers have provided what they wish.

This role gives OPEC a great deal of influence over oil prices but at the cost of varying production to maintain that influence and to balance supply with world demand.

World oil prices remain sensitive to any future hostilities in the Persian Gulf, an area through which one-sixth of the industrialized world's oil moves. Aware of their vulnerability to oil supply disruptions, a number of OECD countries formed the International Energy Agency (IEA) in 1974 and agreed to share their oil supplies in the event of a major supply disruption. In addition, several of these countries, notably the United States and Japan, have created emergency oil stockpiles.





TRENDS IN WORLD CRUDE OIL RESERVES, 1970-89

OPEC members' denomination of established crude oil reserves is growing, suggesting their importance in future production.

Recent new estimates have boosted world oil reserves and highlighted OPEC's dominance in the world oil market. Since 1987, proven world oil reserves (excluding oil sands and oil shale) have jumped by a massive 40 per cent to 990 billion barrels (154 billion m^3), enough to last 47 years at current production rates. Much of this increase occurred in five OPEC countries (four of them Persian Gulf producers): Saudi Arabia, Iran, Iraq, the United Arab Emirates, and Venezuela. These countries increased their reserve estimates by a total of 86 per cent not only by announcing discoveries of new oil fields but also by raising their estimates of the recoverable oil in fields already known.

The Middle East alone now holds two-thirds of the world's oil. OPEC countries have more than three-quarters of total world proven oil reserves, and five OPEC producers account for 65 per cent of world reserves: Saudi Arabia, Kuwait, Iran, Iraq, and the United Arab Emirates. The one-quarter of world oil reserves outside OPEC are divided as follows: developing countries, notably Mexico, 9 per cent; centrally planned economies, especially the USSR, 9 per cent; and the OECD countries 6 per cent.

What does the future hold for world oil supply, demand, and prices? A broad range of opinion believes that the Middle East will regain its position as the world's leading supplier in the 1990s as demand grows and non-Mideast supplies, especially in North America and the North Sea, decline. Mideast producers will then once again be in a position to raise oil prices as they did in the 1970s and early 1980s.

However, this prediction could be upset by possible developments in technology on both the demand side (eg. new fuel-efficient vehicles) and the supply side (eg. offshore production platforms). Production from new sources outside OPEC could also exceed expectations. Countries which have in recent years become substantial oil producers in their own right include

What are reserves?

Reserves are estimated quantities of recoverable primary energy sources. Reserves are continually being reduced by ongoing production and increased by the discovery of new resources. As long as the rate of addition to reserves on average keeps pace with the rate of production, the reserve level will be maintained. If the rate of addition exceeds the rate of production, reserves will increase.

Reserves vary in quality and ease of recovery and are often of different types. Normally the highest-quality (most valuable) and most accessible portions are produced first, with production gradually moving towards lower-quality, less accessible reserves. The estimate of how far this movement can go, that is, the size of the recoverable reserves, depends largely on assumptions about future energy prices and advances in recovery technology. Therefore, even if no further discoveries are made, reserves can increase if energy prices rise higher than expected or if innovations in recovery technology make marginal reserves unexpectedly attractive.

In a conventional reservoir, on average only about 30 per cent of the crude oil can be recovered using natural pressure to move the oil to the surface. After this, more oil can be taken if "secondary" recovery techniques such as water flooding or gas injection are used to increase pressure artificially. Even then much oil is left that can be brought to the surface with "tertiary" or "third generation" recovery techniques such as carbon dioxide flooding, chemical flooding, or in situ combustion. The viability of these progressively more costly levels of effort depends both on oil prices and on advances in technology.

Similar gradations can be seen between and within other types of potential crude oil reserves such as bitumen, oil shales, and frontier resources. All these variations, combined with limitations in the information available even on known reserves, make reserve estimates an uncertain and sometimes contentious matter.

Brazil, India, Norway, Egypt, Malaysia, Colombia, and North Yemen. In 1987, these new non-OPEC sources produced enough extra crude to more than offset the decline in production from older non-OPEC producers such as the United States.

IN CANADA

Self-sufficiency in oil

Canada's oil production in 1988 was about 630 million barrels (100 million m^3) and accounted for 2.8 per cent of the world total. Canada is now self-sufficient overall in crude oil, producing 16 per cent more oil than it consumes. However, it is not self-sufficient in the light and medium crudes, which represent more than 80 per cent of domestic crude consumption and are the kinds used by most Canadian refineries. In 1988, just under two-thirds of Canada's oil production was conventional light and medium crude, about one-tenth was light synthetic oil from the Syncrude and Suncor plants in northern Alberta's oil sands, and about 7 per cent was lighter hydrocarbon liquids (condensates and pentanes plus). The remaining 20 per cent of Canadian production, consisting mainly of heavy oil and bitumen obtained from oil sands but not upgraded, was mostly exported to American markets.

Canada is now a net exporter of oil, selling abroad half again more oil than it buys. In 1988, about two-fifths of production, or 260 million barrels (41 million m^3), were exported. The export quantities, which were sold mainly to American refineries, were split about 3:2 between heavy and lighter crudes.

For total Canadian oil supply to exceed total demand in the mid-1980s would have surprised observers a few years earlier. In the early 1980s the consensus among forecasters was that Canadian oil production would lag behind demand until the 1990s. However oil demand fell sharply across the country, and oil production increased. When oil prices fell in 1986, drilling also fell – and quite sharply at that. However, oil companies responded by cutting costs, improving efficiency, and focussing on lower-risk drilling prospects that yielded returns more quickly. Governments assisted by reducing taxes and royalties and by giving incentive grants. As a result, oil production increased, particularly heavy oil.

Oil imports to Canada in 1988 were about 160 million barrels (25 million m^3), equivalent to one-quarter of production. Imports were almost entirely of light and medium crude delivered to refineries in the Maritimes and Quebec. About two-thirds of these imports in the east were balanced by exports in the west and amounted to a less expensive way of serving Eastern Canada than by transporting the oil from Western Canada. About one-third represented net imports of light and medium crude beyond what Canadian sources would have been capable of supplying.

Light Oil, Heavy Oil, and Upgrading

The many compounds of hydrogen and carbon vary in the ratio of hydrogen and carbon atoms their molecules contain. Compounds whose molecules have relatively high hydrogen to carbon ratios are lighter, less viscous, and more volatile than compounds with lower hydrogen to carbon ratios.

In nature these "hydrocarbons" are found in blends. Crude oil, like natural gas or coal, is such a blend of hydrocarbon compounds. Natural gas has a much higher average hydrogen to carbon ratio in its compounds than crude oil and is thus so much lighter that it is a gas at normal atmospheric pressure. (It is mainly methane, CH_4, the simplest hydrocarbon and also the one with the highest ratio of hydrogen to carbon.) Coal on the other hand has a much lower average hydrogen to carbon ratio than crude oil and thus is a solid.

Similar grades exist with crude oil. Light crude oils, with high average hydrogen to carbon ratios, are light coloured and freely running at atmospheric temperatures, whereas heavy crude oils, with lower average hydrogen to carbon ratios, are dark and thick. Generally the lower the hydrogen to carbon ratio the greater the impurities, particularly sulphur, which must be removed to reduce noxious emissions from the combustion of oil products.

An oil refinery breaks down a crude oil "blend" into its separate hydrocarbon "fractions", which range from gases through gasoline-like light distillates and kerosene-like middle distillates to residuals like heavy oil and asphalt. The refinery then processes and recombines these fractions into marketable liquid fuels. A heavy crude oil will have a larger proportion of heavier fractions and a smaller proportion of lighter fractions than a light crude oil.

The values of different crudes are determined by the market values of their main component fractions. In general, lighter crudes make a greater proportion of more valuable products, besides being easier to recover, transport, and refine.

Upgrading processes are applied to heavier crudes to raise their value by increasing their hydrogen to carbon ratio to produce a lighter "synthetic" crude. This is done by either removing some of the carbon ("coking"), or adding hydrogen ("hydrocracking"), or a combination of both. Upgrading is in use at many Canadian refineries. It also provides the means for changing the bitumen in Alberta's oil sands into a light synthetic crude oil. As lighter crude reserves are depleted and production moves increasingly to heavier crudes, upgrading will become more and more important in Canada and around the world.

Canada consumed 554 million barrels (89 million m³) of refined petroleum products in 1988. The major products consumed were gasoline and diesel fuel, which together accounted for 58 per cent of consumption.

Canada's oil consumption by product, 1988

	million barrels	thousand m³	per cent
▸ gasoline	215	34	39
▸ diesel fuel	105	17	19
▸ aviation fuel	32	5	6
▸ light fuel oil	42	7	7
▸ heavy fuel oil	56	9	10
▸ petrochemical, feedstock & others	104	17	19
Total	**554**	**89**	**100**

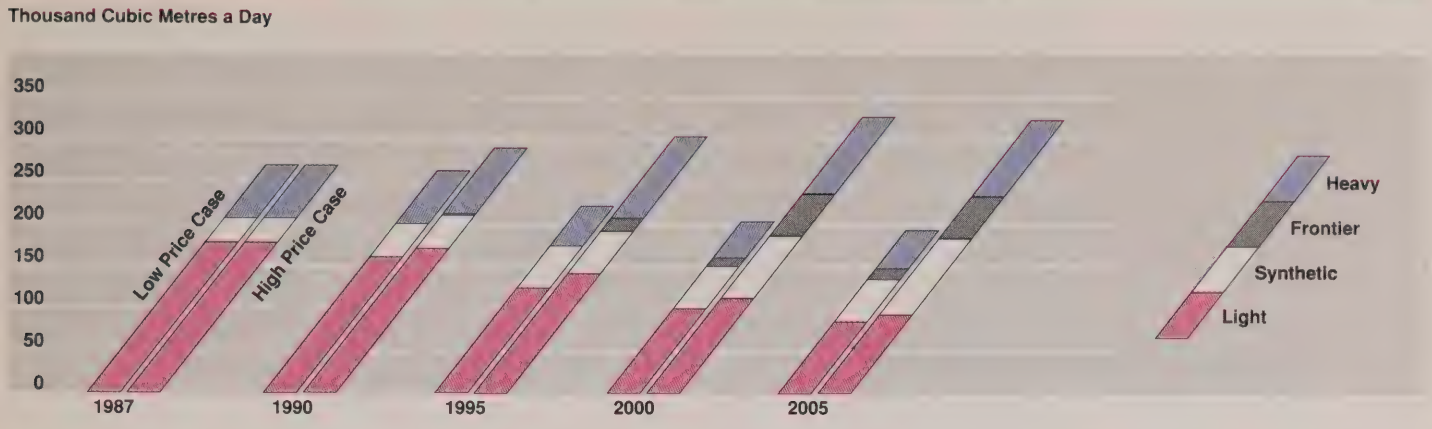
MAJOR OIL FIELDS AND PIPELINES IN CANADA

The bulk of Canadian oil fields are located in the Western Sedimentary Basin.

Supply Outlook

How long Canada will remain a net exporter of crude oil is uncertain. Canada's need for light crude is expected to grow slowly, while Canada's production of light crude from conventional sources will probably decline steadily. Canada will therefore have to import increasing amounts of light crude unless new supplies become available from unconventional sources such as the oil sands and frontiers. But the projects that will bring unconventional sources into production will become economic only with buoyant world oil prices.

The decisive role of world oil price levels is recognized in the National Energy Board's 1988 forecast of Canadian energy supply and demand until 2005. If world oil prices are high ($30 US a barrel in 1987 dollars), Canadian production is forecast to grow 15 per cent and Canadian net exports will increase. If oil prices are low ($20 a barrel), domestic oil production will drop to about three-quarters of the 1987 level and net imports of light crude will rise to 40 per cent of domestic requirements. In both cases, production of light crude from conventional sources will fall by more than half. The difference is that when prices are high, unconventional sources become economic to exploit. The shortfall in conventional crude would thus be made up by a jump in the production of synthetic oil from bitumen and heavy oil upgrading and by new supplies from frontier sources such as the East Coast Offshore, the Beaufort Sea, the Mackenzie Delta, and the Arctic Islands.



CANADIAN OIL PRODUCTION PROJECTIONS, 1987-2005

As production of light crude declines, synthetic oil and frontier crude will become increasingly important, especially if prices rise.

Over the long term the development of frontier oil reserves is generally regarded by the oil industry to be inevitable. Sooner or later, oil prices are expected to rise enough or production technology to improve enough for frontier production to become viable.

Falling prices and the oil industry

In 1985, the federal government and the oil-producing provinces signed the Western Accord, which deregulated the oil industry by freeing buyers and sellers of oil to negotiate prices and volumes in an open market. The agreement replaced the National Energy Program of 1980, which had provided for a "made in Canada" oil price.

But after the boom year of 1985, Canada's oil industry in 1986 suffered its most severe decline in forty years with the collapse of world oil prices. The number of oil and gas wells completed fell by half, and capital spending declined by one-third, from the levels of 1985. Many jobs were lost, especially in skilled technical positions.

The price collapse also made it difficult to pursue costly production projects, such as Syncrude's major expansion of its Fort McMurray oil sands plant, Husky Oil's Lloydminster heavy oil upgrader, and Newfoundland's offshore Hibernia oil field.

The recovery in oil prices in 1987 restored some optimism to the industry's prospects. The federal government removed the Petroleum and Gas Revenue Tax (PGRT). The Canadian Exploration and Development Incentive Program, announced in 1987 to last until the end of 1989, provided exploration and development grants. Provincial governments lowered royalties and provided other assistance to their producers, while industry worked to improve efficiency and reduce costs.

In 1988, the federal government announced large financial support packages for four energy megaprojects: the Husky upgrader (which will produce 46,000 barrels a day of light crude oil), the Vancouver Island Gas Pipeline, the OSLO oil sands project, and Hibernia (which could produce 110,000 barrels a day). The support total is $2 billion in grants and $3.1 billion in loans and loan guarantees. But later in 1988 industry confidence was tested again when a new drop in oil prices, followed by a recovery, made it clear that world oil prices actually showed few signs of stability.

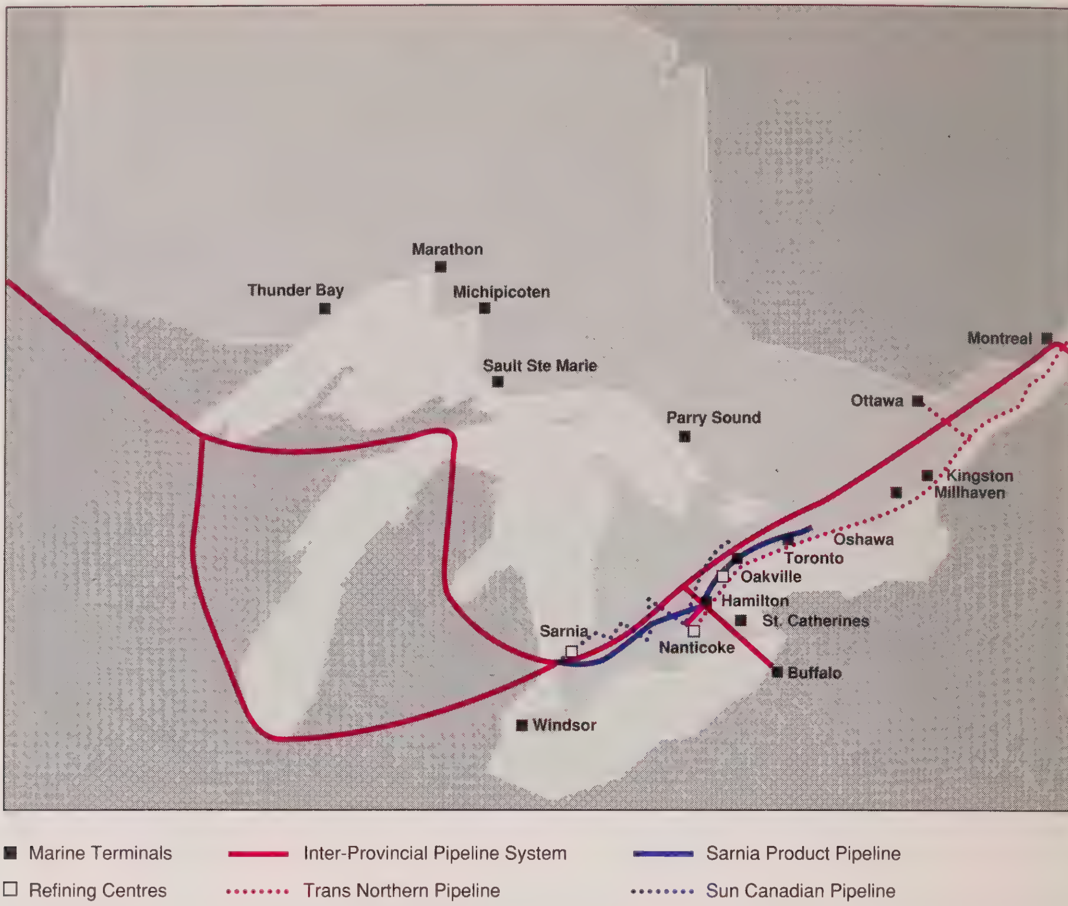
IN ONTARIO

Supply: still dependent on outside sources

Ontario in 1988 produced about 1.2 million barrels (0.2 million m^3) of crude oil, an increase of 40 per cent over 1987, as a result of new wells discovered since 1983. Nevertheless, Ontario's oil production amounts to less than 1 per cent of the province's requirements, about 2.5 days' supply. Most of Ontario's production of oil and gas is located in the southwestern part of the province. (The first commercial oil well in North America was drilled at Oil Springs, near Sarnia, in 1858.) There are also oil shale deposits in the Great Lakes region of southern Ontario and in the James Bay lowlands of northern Ontario, but these are not economically recoverable.

About 95 per cent of the oil Ontario consumes comes from Western Canada via the Interprovincial Pipe Line (IPL) system. Ontario also imports small volumes from the United States, chiefly Michigan, which account for about 4 to 5 per cent of its needs.

The decline in Western Canadian reserves of light crude oil means that Ontario may have to look elsewhere for its light oil supply in the future. Foreign oil could be imported into Ontario from Montreal, which would require the flow in the Sarnia-to-Montreal pipeline to be reversed, or from the U.S. Gulf Coast by way of the U.S. mid-continental pipeline system.



ONTARIO'S OIL PIPELINE SYSTEM

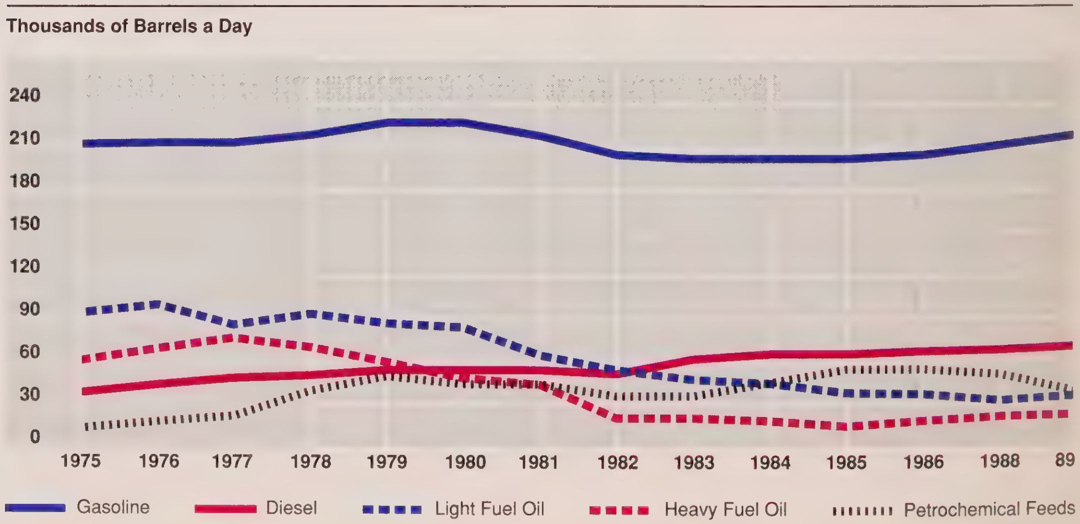
More than ninety per cent of Ontario's oil comes from western Canada by way of the Interprovincial Pipe Line System.

Consumption: well below the peak in the 1970s

Ontario's annual consumption of oil products peaked at 207 million barrels (33 million m^3) in 1979. It then fell by almost 25 per cent over the next four years, as conservation and oil substitution programs, together with recession in the early 1980s, reduced the role of oil in Ontario's energy mix. After 1983, consumption of Ontario petroleum products began to grow again as the economy recovered, but only gradually. By 1988, Ontario demand (170 million barrels; 27 million m^3) was still about 17 per cent below its 1979 peak.

Motor gasoline is Ontario's major petroleum product, accounting for about 45 per cent of consumption. Although the population of registered passenger automobiles has increased by 19 per cent to 4.5 million in the last eight years, the greatly improved fuel efficiency of new cars has held down gasoline consumption, which in 1988 was still 8 per cent below its 1979-80 peak.

Even greater declines in consumption have occurred through greater efficiency and conversion to other fuels. Since 1979, demand for light fuel oil, used mainly to heat homes, has dropped by 53 per cent, and demand for heavy fuel oil, used mainly in industrial boilers, has



USE OF SELECTED REFINED OIL PRODUCTS IN ONTARIO, 1975-88

Gasoline remains dominant, but diesel fuel demand is growing strongly.

dropped by 49 per cent. Also in 1988, 22 per cent less petrochemical feedstocks was used to make such things as plastics and nylon (though natural gas liquids are increasingly being used in place of oil).

But consumption of some other oil products has been growing strongly. For instance, since 1979 diesel fuel consumption has grown 14 per cent.

A large and competitive refinery industry

Ontario is Canada's leading petroleum refining region. The province's six refineries have an annual capacity of 183 million barrels (29 million m^3). Most of the province's refinery capacity is located in Sarnia; the rest is in the Oakville-Mississauga area west of Toronto and at Nanticoke on Lake Erie.

Ontario's refineries produce enough petroleum products to meet the province's needs, with some left over for export to other provinces and the United States. However, in practice Eastern Ontario is mostly supplied from Montreal to save on transportation costs. Gasoline accounted for about 35 per cent of Ontario refinery production in 1988, diesel fuel for 12 per cent, and petrochemical feedstocks for 10 per cent.

Although a stronger economy has improved refiners' profits, competition in the Ontario gasoline market, especially in the urban south, remains intense. This is partly because independent marketers (ie. those with no refining capacity of their own) can easily import gasoline from the United States whenever it is cheaper for them to do so than to buy from Ontario refiners.

ONTARIO REFINERIES AND CAPACITIES, JUNE 1988

Ontario refineries produce more than enough petroleum products to meet provincial needs.

Location	Company	Capacity (thousands of barrels a day)
Sarnia	Esso Petroleum	125
	Shell Canada	71
	Suncor	70
Nanticoke	Esso Petroleum (formerly Texaco Canada)	95
Oakville	Petro-Canada	81
Clarkson	Petro-Canada	60
		Total 502

Note: The Polysar/Nova plant at Sarnia has undergone process modifications and is no longer a significant supplier of petroleum products.

Ontario refiners may face new investments some time in the 1990s to meet the growing demand for lighter products, such as gasoline and diesel fuel. They will also need substantial investments to comply with more stringent product quality standards, including completely lead-free gasolines, reduced gasoline volatility and lower sulphur limits for fuel oil and diesel. The quality of Ontario refiners' crude oil feedstocks may also decrease as Western Canada's light oil reserves decline, requiring changes in refining equipment. Major refinery upgrading projects in recent years include Suncor's $350 million hydrocracker, installed at its Sarnia refinery in 1983-84, and an $80 million upgrading program at the Nanticoke refinery.

Natural Gas

AROUND THE WORLD		IN CANADA	IN ONTARIO
Natural gas consumption is increasing globally, especially in new markets outside North America. Known world reserves will last 60 years at current production rates.	**Natural gas is growing in global importance and now meets 20 per cent of the world's primary energy needs. Canada and the United States are among the most developed markets. A clean-burning, efficient heat source for buildings and industry, it is increasingly used for electricity generation, chemicals manufacturing, and to power road vehicles. Natural gas is transported primarily by pipeline but can also be delivered by seagoing liquefied natural gas (LNG) tankers.**	*Western Canada is the major source of natural gas. Market uncertainties are delaying development of large frontier resources, which will be costly to develop. Exports are increasing and may grow much larger with deregulation and free trade.*	*Natural gas use in Ontario did not grow in total from 1976 to 1983, as efficiency improvements and declines in its use for electricity generation were balanced by growth in number of consumers. However, natural gas use has grown by 20 per cent since 1983.*

About Natural Gas . . .

Since the major component of natural gas, methane, has the highest hydrogen to carbon ratio of any hydrocarbon fuel, natural gas produces less carbon dioxide than other fossil fuels when burned. The processing of natural gas does release carbon dioxide, and methane released to the atmosphere also contributes to global warming. Its high hydrogen content makes natural gas valuable in the upgrading of heavy oil and the manufacture of ammonia-based fertilizers.

In Canada, about 12 per cent of the natural gas supply comes from reserves associated with crude oil in the same geological formation. In these associated reserves, on average about 1200 cubic feet (34 cubic metres (m^3)) of natural gas is produced with each barrel of oil, equivalent to about one-fifth the energy value of the oil.

Unlike crude oil, recovered natural gas normally requires little processing to be made into a suitable fuel for consumers. It is necessary to remove contaminants that lower the thermal value, such as carbon dioxide, and noxious fumes, such as hydrogen sulphide.

To move natural gas by pipeline costs four times as much as to move the energy equivalent in crude oil, and by ocean-going tanker it costs 10 times as much. Piped gas requires high pressures maintained by frequent compressor stations, while tanker transport requires liquefaction and super-refrigeration.

Natural gas liquids are light hydrocarbons often found in liquid form associated with gaseous methane. They consist mainly of ethane, propane, and butane, which can be stored as liquid in pressure tanks for ease of handling and are used both for energy and for petrochemical feedstocks.

AROUND THE WORLD

Natural gas meets about 20 per cent of the world's primary energy needs, putting it in third place behind crude oil (38 per cent) and coal (31 per cent). Around the world natural gas consumption continues to grow. From 1979 to 1988 its share of the world's energy use grew by 2 percentage points. Over the same period, world's total natural gas consumption rose by 28 per cent. This growth occurred outside North America, where natural gas consumption over the last decade first declined and then recovered partially.

There is an abundant world supply of natural gas. At the end of 1988, total world proven reserves were estimated to be 3950 trillion cubic feet [Tcf] (112 trillion cubic metres (m^3)), which at 1988 production levels would last about 60 years. The USSR and Middle East countries hold the largest shares of world proven reserves, with 38 per cent and 30 per cent respectively. The United States holds 5 per cent (down from 7 per cent in 1981) and Canada just over 2 per cent.

The United States and the Soviet Union dominate the global natural gas business, together accounting for two-thirds of production and three-fifths of consumption. However, the United States is a net importer, mainly from Canadian sources, while the Soviet Union is self-sufficient and a major exporter to European countries. American reserves are much smaller: at 1988

production levels Soviet reserves would last about 55 years and American reserves about 11 years.

Most market growth has occurred in the centrally planned economies of the Soviet Union and Eastern Europe, where from 1979 to 1987 gas production increased by 74 per cent and consumption by 61 per cent. Gas consumption in Japan and the newly industrializing countries of Asia is also growing fast.

WORLD PROVEN RESERVES OF NATURAL GAS IN 1988, BY COUNTRY AND BY REGION

On a world scale, North American reserves of natural gas are small.

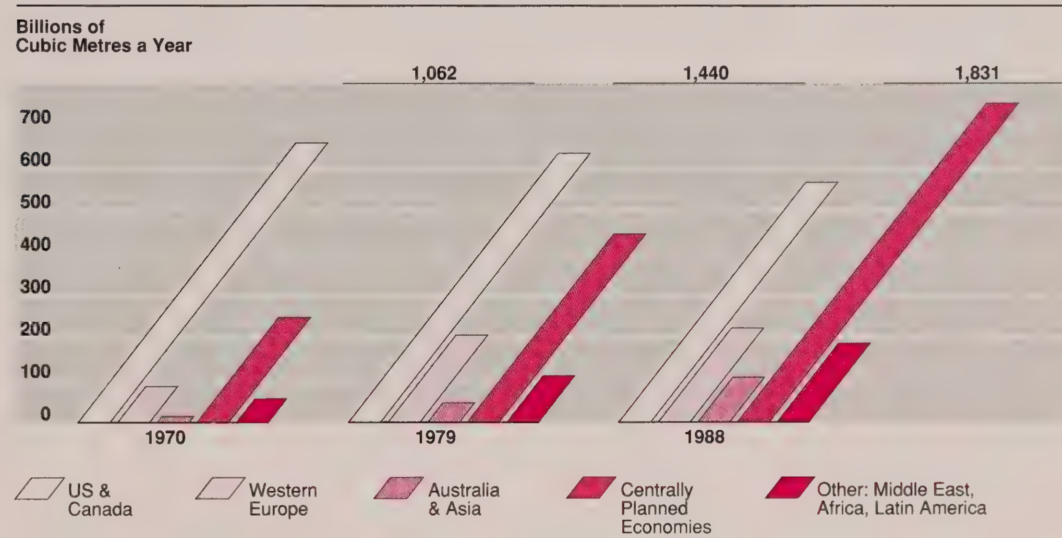
Trillions of Cubic Metres	
44.2	**Centrally Planned Economies:** USSR — 42.5 / Eastern Europe & China — 1.7
47.4	**Middle East** — 33.5 / **Africa** — 7.2 / **Latin America** — 6.7
8	**North America:** USA — 5.3 / Canada — 2.7
5.7	**Western Europe**
6.8	**Asia and Australasia**

The expanding European natural gas market is becoming increasingly competitive. With the completion of the Trans-Siberian pipeline in 1984, the USSR increased its supply of gas to central Europe. Algeria is aggressively marketing supplies in western Europe and in 1988 resumed liquefied natural gas sales to the United States. The United Kingdom has large offshore fields, and Norway is committed to developing its large North Sea gas fields. The Netherlands, where Europe's first giant natural gas reserves were discovered, remains a major supplier.

In the United States, natural gas consumption remains below its 1979 peak but is rising. The government has reduced supply and price controls and encouraged competition. In 1988 about 7 per cent of the natural gas consumed in the United States was imported from Canada, mainly to California and the U.S. Mid-West.

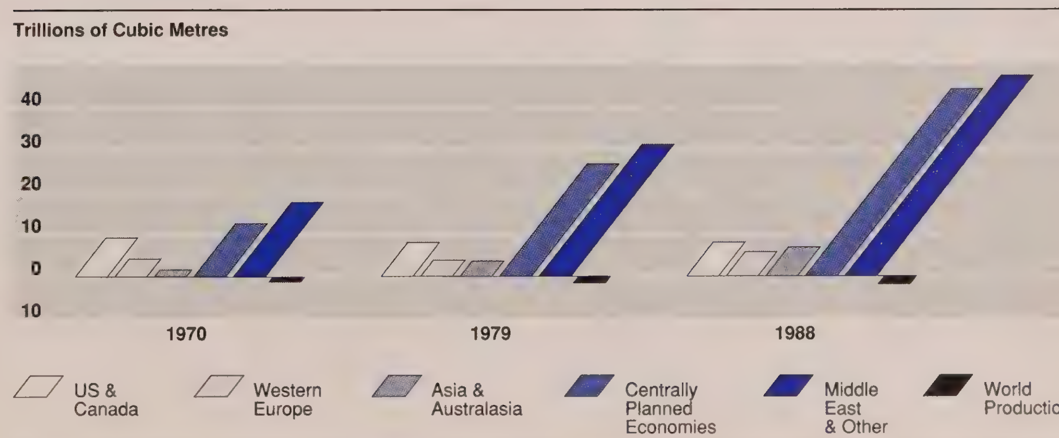
CHANGES IN WORLD NATURAL GAS CONSUMPTION, 1970-88

Natural gas consumption is growing globally but has declined in North America.



GROWTH IN WORLD RESERVES OF NATURAL GAS, 1970-88

World natural gas reserves are expanding, especially in the Middle East and USSR.



NATURAL GAS PRODUCTION AND CONSUMPTION IN SELECTED COUNTRIES AND REGIONS IN 1988

Natural gas production and consumption are concentrated in the USSR and the USA.

IN CANADA

Supply and demand

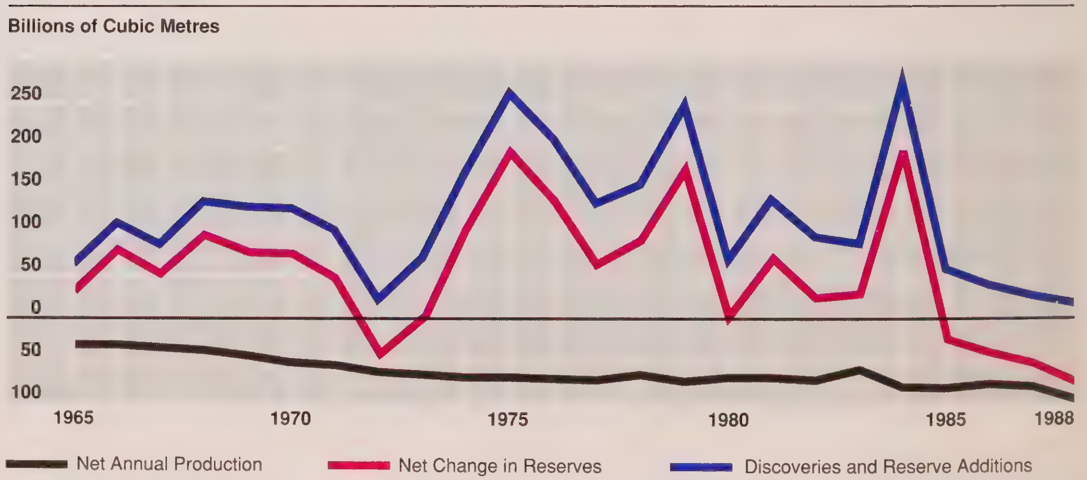
The National Energy Board estimated Canada's remaining established reserves of "marketable" natural gas (of suitable quality for end-use consumption) at the beginning of 1988 to be 85 Tcf (2.4 trillion cubic meters). Of this total, 68 Tcf (1.9 trillion cubic meters) are in the conventional producing areas: mainly Alberta, British Columbia, and Saskatchewan, with small amounts in southwestern Ontario and Eastern Canada. The remaining 17 Tcf (0.5 trillion cubic meters) are in frontier areas: mainly the Arctic Islands and the Mackenzie Delta/Beaufort Sea, with small amounts in the southern parts of the Yukon and Northwest Territories.

Large Canadian reserves besides these are known but have yet to be assessed. No established gas reserves have yet been recognized by the Board for the east coast offshore region, although several discoveries have been made. Another possible future source is the deep basin or "tight gas" reserves of Western Canada, estimated by some to have larger potential even than conventional Western Canadian reserves. These resources require costly recovery techniques and may not become economic to exploit until the next century.

At 1988 net production rates, Canada's remaining established reserves (including those in frontier areas) would last about 28 years, a decrease of six years since 1985 as a result of declining reserves.

Natural gas is currently available to Canadians from Vancouver to Quebec City. Gas moves east from Alberta through to Montreal by way of the TransCanada PipeLines System or by the Great Lakes Gas Transmission System, which branches off the TransCanada pipeline in Manitoba and proceeds through the United States to Sault Ste. Marie and Sarnia. The TransQuebec & Maritimes pipeline carries gas from Montreal to Quebec City.

Canadian consumption of natural gas has grown steadily since the 1960s except for the period from 1979 to 1983, when domestic demand fell as conservation and increased efficiency of gas use more than offset the effect of consumers' switching from oil to gas. From 1983 to 1988 demand rose by more than one-quarter. Since natural gas is used for heating, annual consumption is significantly affected by the extent of cold weather.

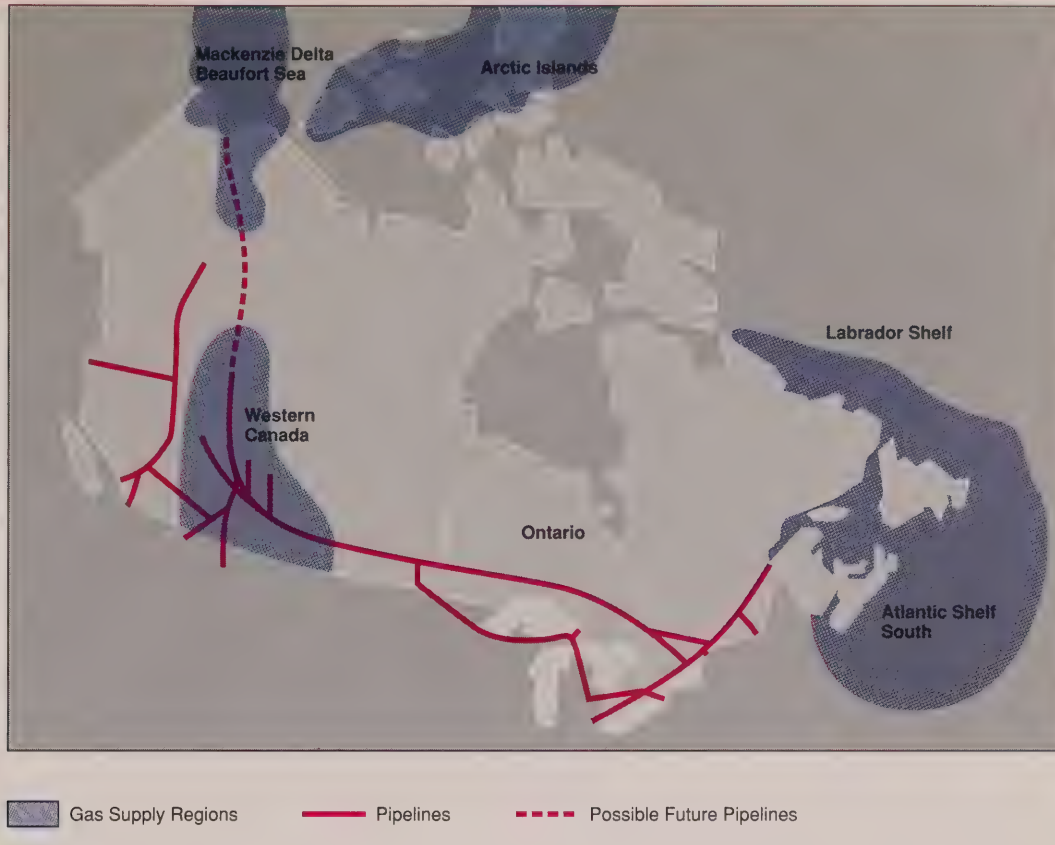


ANNUAL CHANGES TO CANADIAN NATURAL GAS RESERVES

Canada's natural gas discoveries and reserve additions have not replaced production since 1985.

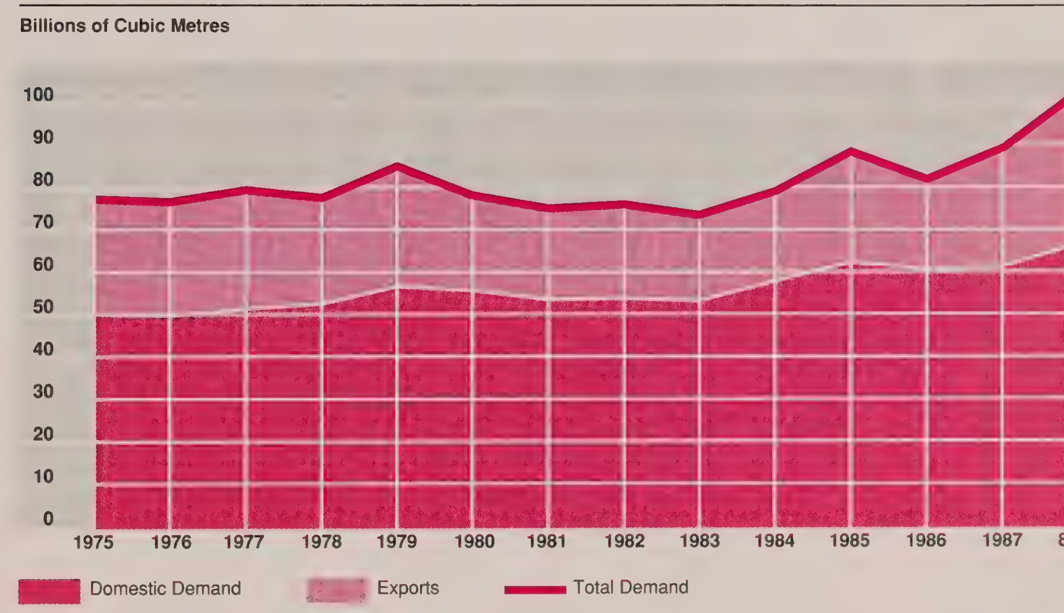
MAJOR NATURAL GAS SUPPLY REGIONS AND PIPELINES IN CANADA

Canada's conventional natural gas reserves are located primarily in the western provinces. Gas is transported to eastern markets by TransCanada PipeLines Limited.



DEMAND FOR CANADIAN NATURAL GAS 1975-1988

Natural gas demand is growing strongly again in the late 1980s, led by exports.



Deregulation

In October 1985, the governments of Canada and the gas-producing provinces (Alberta, Saskatchewan and British Columbia) entered the "Natural Gas Markets and Prices" Agreement. This Agreement shifted the emphasis away from regulation and onto greater reliance on market forces, thus ending a decade of price and export controls.

Among other things, this Agreement ended government-administered prices and paved the way for direct purchase and negotiation of prices between buyers and sellers. Since 1986, there has been an increase in the volume of direct purchases which now account for about a quarter of Ontario's total consumption.

Exports

In 1988 Canadian producers exported some 1.3 Tcf (37 billion m^3) of gas to the United States, an amount equal to 35 per cent of total marketable Canadian production. About four-fifths of these

exports took place under long-term contracts. Export totals rose 70 per cent from 1986 to 1988 as Canadian producers lowered prices and aggressively sought new markets. Exports will continue to grow if new pipeline proposals are approved, Canadian producers are able to gain better access to American pipeline systems, and American supply continues to decline. The National Energy Board believes exports could rise in the next two years by a further one-third to more than 1.8 Tcf (51 billion m^3) a year from projects under construction or awaiting Board approval.

ESSO, Shell, and Gulf Canada have applied jointly to the National Energy Board for a licence to export natural gas from the Mackenzie River Delta to the United States. The licence has been granted conditionally and would allow the production of more than 9 Tcf (255 billion m^3) of natural gas over 20 years beginning in 1996, some of which could serve Canadian consumers. Pipeline facilities would be required and would be the subject of a future application to the Board.

The National Energy Board (NEB) which is responsible for ensuring that reasonably foreseeable Canadian requirements for natural gas are met, modified its export regulation practices and procedures in 1987. They replaced the previously formula based export surplus test with what they call the "market based procedure". The Canada-United States Free Trade Agreement was implemented in January 1989. Under this Agreement, if Canada were to limit exports in the event of a supply shortage or a need to conserve finite resources, Canada would be required to maintain United States access to its customary proportion of Canadian supplies.

IN ONTARIO

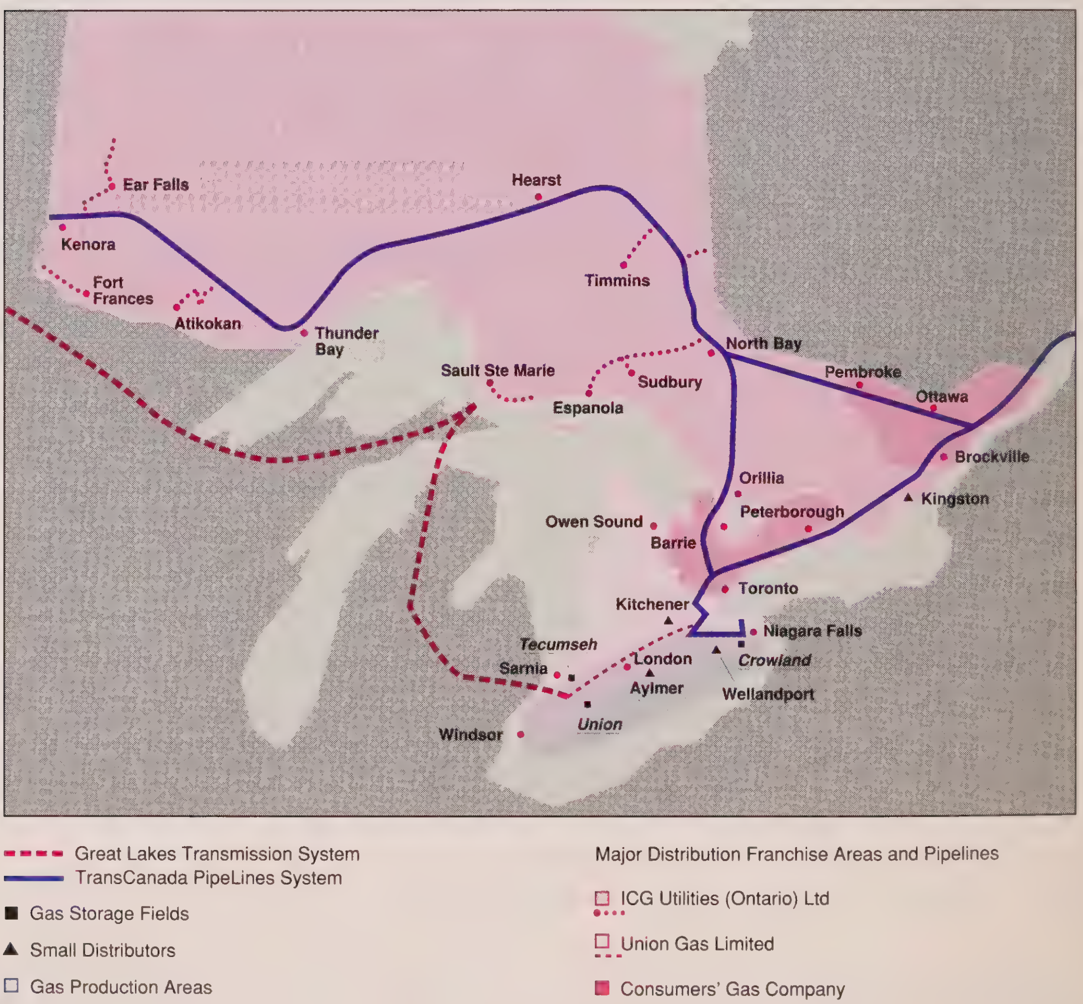
Ontario's gas production

Ontario's production of natural gas accounts for less than 3 per cent of total provincial consumption. Almost all of it is located in the extreme southwest of the province, including reserves under Lake Erie. An additional 1 per cent is supplied by synthetic natural gas manufactured at the Petrosar (now Nova) refinery in Sarnia.

Proven reserves of natural gas in Ontario fell from 1.4 Tcf (40 billion m^3) in 1981 to about 0.6 Tcf (17 billion m^3) in 1986. Ontario's rate of production of natural gas has been falling slowly, reaching 18 Bcf (510 million m^3) in 1988. Gas exploration and development in the province dropped from 61 well completions in 1985 to 16 in 1987, but partly recovered in 1988 to 36 well completions.

NATURAL GAS PIPELINES, DISTRIBUTION SYSTEMS AND PRODUCTION AREAS IN ONTARIO

Natural gas is delivered to Ontario users by three large distribution companies and four smaller ones.



Consumption

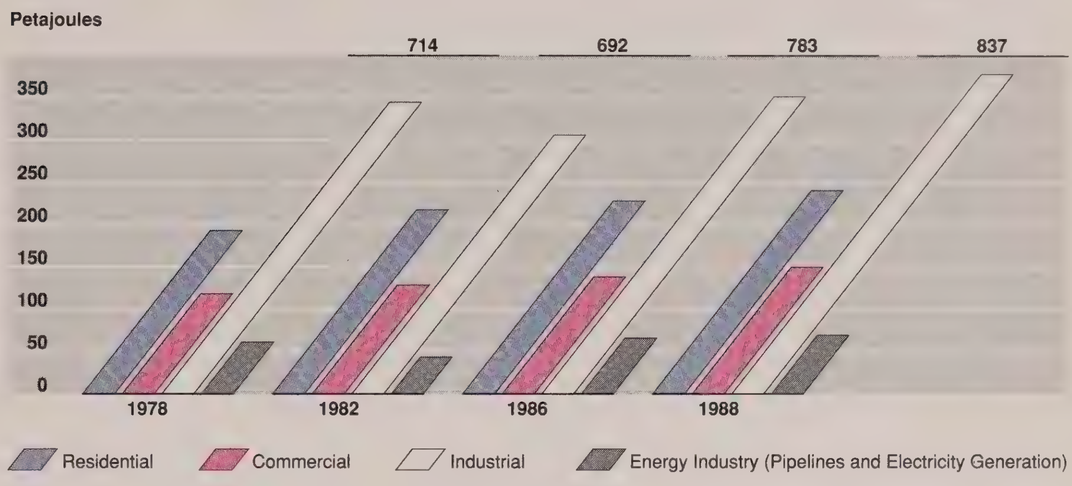
Natural gas use in Ontario grew rapidly in the 1960s and 1970s, tripling in Ontario from 1965 to 1976. From 1976 to 1983, provincial annual consumption fluctuated around 0.7 Tcf (20 billion m^3). The growing number of gas consumers was offset by declines in average consumption per user and a decline in gas-fired electricity generation. Since 1983 demand began to grow again, increasing by 20 per cent from 1983 to 1988.

The largest portion of Ontario's total natural gas consumption occurs in the industrial sector (45 per cent). After a sharp decline in 1982, industrial use has risen again, but it is not much higher than its 1979 peak, because of energy efficiency improvements in industrial processes.

The use of natural gas has grown gradually over the years in both the residential (29 per cent of total consumption) and commercial (18 per cent) sectors. The remaining 8 per cent of Ontario's natural gas consumption is accounted for by the energy industry itself, in such uses as pipeline compressor fuel and industrial electricity generation. Ontario Hydro, whose natural gas use in 1975 amounted to about 7 per cent of total consumption, no longer uses natural gas at Toronto's Hearn Generating Station, and this station is now mothballed.

HISTORIC ONTARIO NATURAL GAS CONSUMPTION BY SECTOR

Residential and commercial use is increasing steadily, while industrial and energy industry use is up.



Distribution

In Ontario, natural gas is distributed primarily by three companies: The Consumers' Gas Company, Union Gas Limited, and ICG Utilities (Ontario) Ltd. Smaller areas are served by the Kingston Public Utilities Commission, the Corporation of the City of Kitchener, Natural Resource Gas Limited, and Wellandport Gas Company Limited.

During the summer, up to one-fifth of the province's annual demand can be stored underground in southwestern Ontario. These storage pools allow an almost constant throughput to be maintained on the TransCanada PipeLines system, and lower the cost of gas to end-use customers. They also provide backup supplies.

Imports of natural gas from the U.S. are becoming a more important source for Ontario. With falling natural gas prices in the United States and restrictions on access to alternative supplies in Canada, Union Gas in 1986 began importing natural gas from the U.S., the first such imports since 1976. An additional pipeline from Michigan to southwestern Ontario has been constructed which will markedly increase the access to imports.

Coal

AROUND THE WORLD

World coal reserves are so vast that the limits to its availability as an energy source are more likely to be set by environmental impacts than by resource depletion.

Coal, the fuel that first made industrialization possible, remains prominent as a staple energy source. Coal provides roughly 30 per cent of the world's primary energy, second only to oil. Worldwide coal consumption has risen by 38 per cent since the price of oil jumped in 1973, reflecting coal's cost-effectiveness in power generation and industrial applications. But environmental concerns cast doubt on the future of coal combustion.

IN CANADA

Canadians are net exporters of coal, mainly to Japan. Four-fifths of the coal consumed in Canada is used to generate electricity.

IN ONTARIO

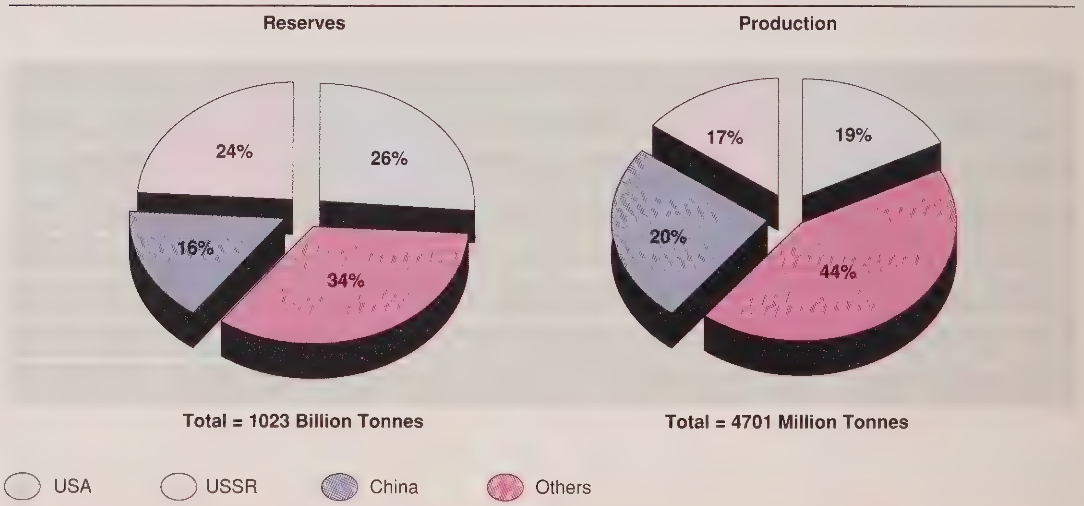
Ontario produces no coal though it consumes large quantities, two-thirds of which are used to generate electricity and most of the rest to make steel.

AROUND THE WORLD

The world has enormous coal reserves, now estimated to be more than 1,000 billion tonnes, equivalent to over 400 years of production at current rates. Half of these reserves are found in, and distributed almost equally between, the United States and the Soviet Union. Both these countries are major coal producers and consumers, but the largest of all is China. Together, these three countries account for over half of world production and consumption.

WORLD COAL RESERVES AND ANNUAL PRODUCTION, 1988

Three countries have the largest reserves and are the biggest producers and consumers of coal: the U.S., the USSR and China.



Types of Coal

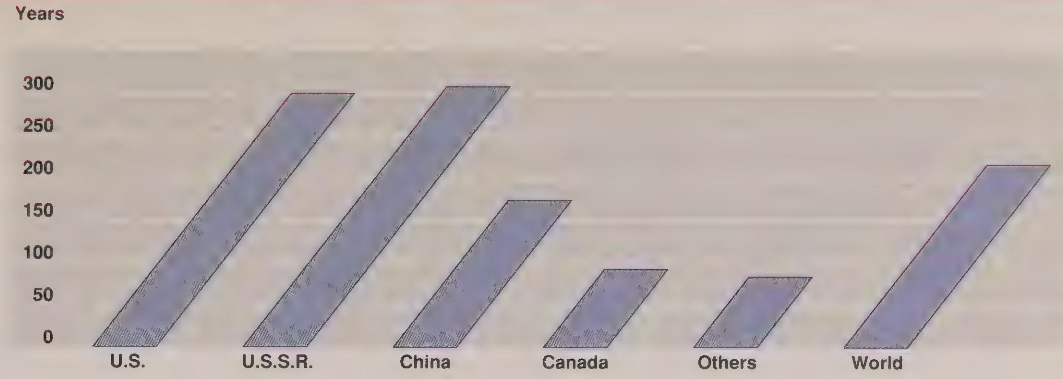
Coal is formed from vegetable matter which has been buried and then subjected to great geological pressure over millions of years. The greater the pressures and the longer the time, the higher the proportion of carbon in the coal and the greater its value as a fuel.

Peat is the first product formed by the burial of swamps and lagoons, and it has the lowest proportion of carbon; in fact peat has not yet become coal. More time and pressure turn the peat into lignite, sometimes called brown coal, which is crumbly when exposed to air. Next in the metamorphosis comes bituminous coal, which is black and solid and widely used for electrical generation and in industry. Eventually bituminous grades turn into anthracite, the highest-quality coal, which is hard, black, and shiny, and suitable for domestic use.

Almost all coal now used in Ontario is bituminous. Until the 1960s anthracite coal was used for domestic coal furnaces. It was delivered by truck to storage bins in house basements, and then shovelled by homeowners into their furnaces. Saskatchewan lignite is used in two of Ontario Hydro's electricity generating stations, where its low sulphur content offsets its lower heating capacity.

LIFE OF ESTABLISHED COAL RESERVES, SELECTED COUNTRIES, 1988

Coal is the most abundant fossil fuel.



IN CANADA

Canada has nearly 7 billion tonnes of recoverable coal reserves, including lignite, or more than 100 years' supply at present rates of production. But in Canada as elsewhere, coal production has increased rapidly. From 1980 to 1988 Canadian coal production grew about 10 per cent a year.

Since 1981 Canada has been a net exporter of coal. Both imports and exports are significant, because the country's largest known coal resources are located in the three westernmost provinces, a great distance from the large Eastern Canadian coal users. Because of transportation costs, Western Canadian coal is more expensive for Ontario users than coal from Pennsylvania and Ohio.

In 1988, coal exports (33 million tonnes) were twice imports (16.5 million tonnes). By far the largest market for Canadian coal exports was Japan, which purchased 17 million tonnes, mostly of metallurgical coal for use in the iron and steel industry. Other important markets for Canadian coal were South Korea and Brazil.

Canadian coal production, totalling 70 million tonnes in 1988, occurs almost entirely in the three westernmost provinces (percentages are: Alberta 42, British Columbia 35, Saskatchewan 17), with small additional amounts from Nova Scotia (5 per cent) and New Brunswick (1 per cent).

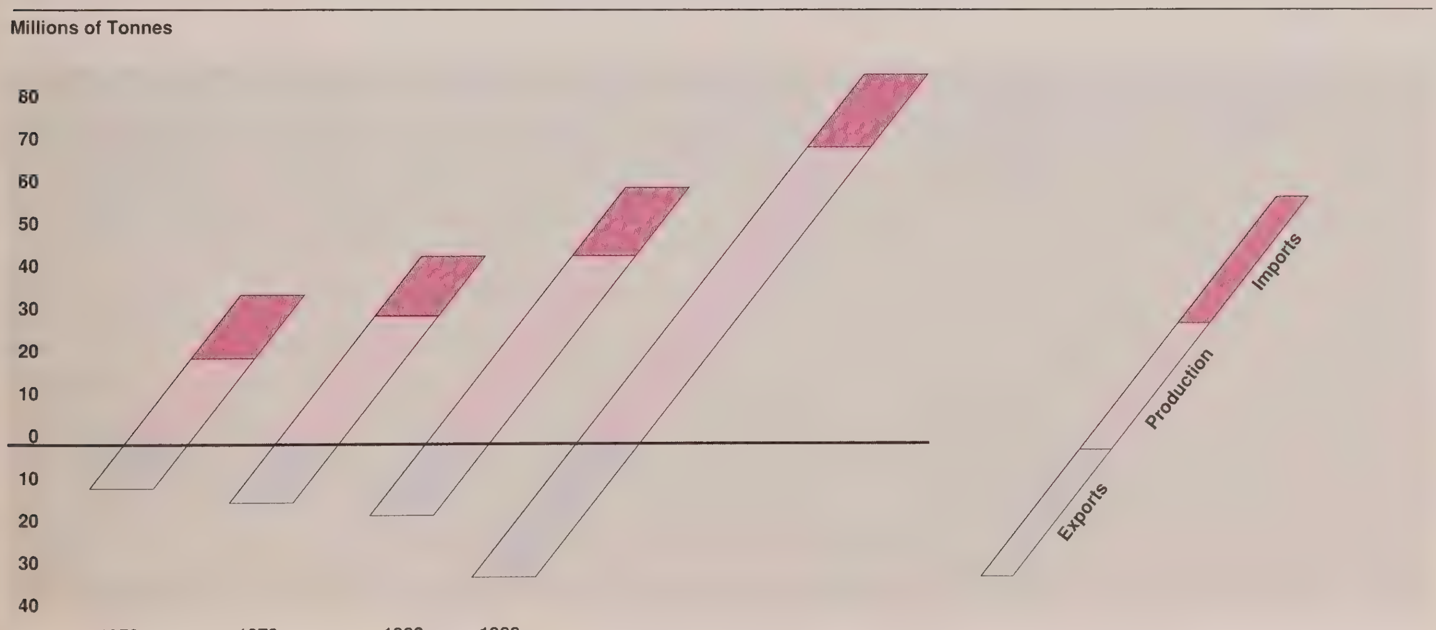
Total coal consumption in 1988 was 56 million tonnes, over 80 per cent more than ten years earlier. However, in relative terms as an energy source, coal now accounts for only 12 per cent of Canadian primary energy consumption, compared to about one-half in the mid-1950s.

In Canada coal is mainly used (over 80 per cent) to generate electricity. Alberta and Ontario are the largest users of coal-fired electricity. Saskatchewan, New Brunswick and Nova Scotia are significant users too. In 1988, coal-fired generation provided 21 per cent of electrical power nationally. The National Energy Board has forecast that the amount of coal burned in Canada might increase by as much as 50 per cent by the year 2000, and coal-fired generation would produce up to 16 per cent of Canada's electricity. However, the environmental impact of coal burning on carbon dioxide emissions has led some to question increases in its use.

Steel manufacturing accounts for almost 10 per cent of national coal consumption. Roughly 4 per cent is used for process heating in other industries.

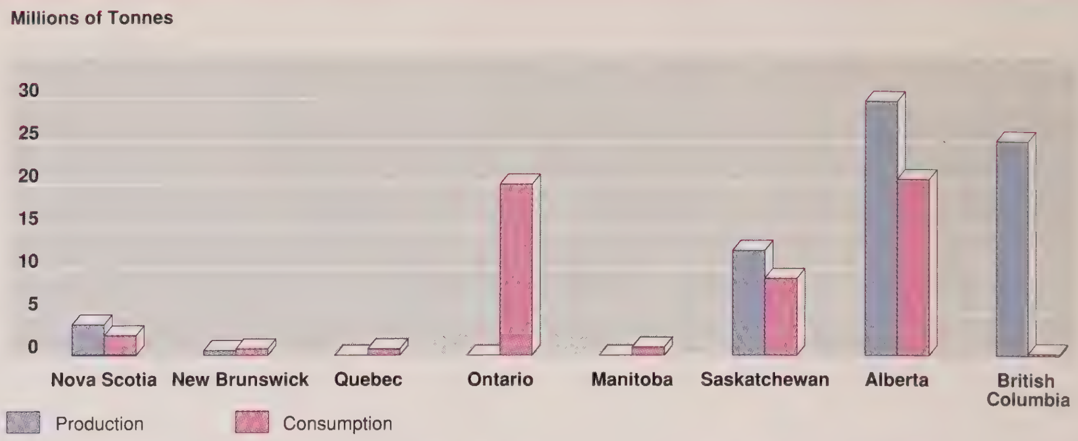
HISTORICAL CANADIAN COAL SUPPLY, DEMAND, AND TRADE

As Canada's coal production has increased, exports have grown larger than imports.



CANADIAN COAL PRODUCTION AND CONSUMPTION BY PROVINCE, 1988

Almost all of Canada's coal production occurs west of Manitoba.



IN ONTARIO

Ontario consumed 20 million tonnes of coal in 1988, accounting for 37 per cent of Canada's total consumption. In 1988, coal provided 15 per cent of Ontario's primary energy requirement, down from 20 per cent in 1970.

All coal used in Ontario comes from outside the province: in 1988 about three tonnes from the United States for every tonne from Western Canada. Ontario Hydro has expanded its use of Western Canadian coal for two reasons: to diversify its supply sources and to get a low-sulphur grade of coal that can be blended with higher-sulphur American coal for lower acid gas emissions.

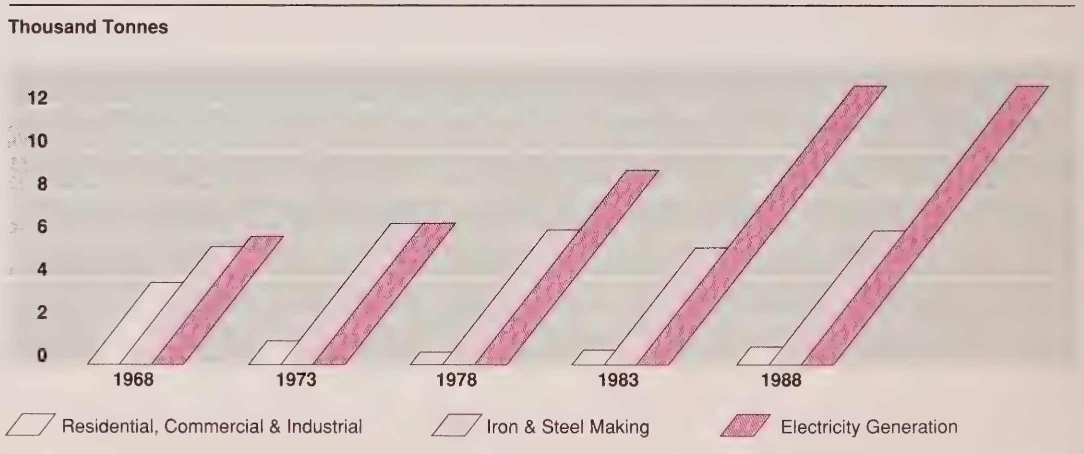
Almost all the coal consumed in Ontario is used either to generate electricity (65 per cent in 1988) or to make steel (31 per cent). Other uses, such as in cement-making, accounted for 4 per cent of Ontario coal use in 1988.

The amount of coal burned in Ontario to generate electricity rose from 6 million tonnes in 1968 to 13 million tonnes in 1988. But constraints on acid gas emissions and the lower cost of nuclear-generated electricity will cut into coal-fired generation. In 1988, coal accounted for only one-quarter of Ontario's electricity generation.

The demand for coal for metallurgy, mainly to make coke to feed the blast furnaces for smelting iron ore, varies with the demand for steel. Demand has increased since the steel industry's 1981-83 slump but has not regained the peak level of 1979.

HISTORIC ONTARIO COAL CONSUMPTION BY SECTOR

Electricity generation accounts for most of the increase in Ontario coal consumption over 20 years.



Liquid Fuels from Coal

During the 1970s and early 1980s high oil prices were an incentive to find better ways to make liquid fuels such as gasoline or diesel oil from coal. Essentially the task is to increase the hydrogen to carbon ratio by removing some of the carbon and/or adding hydrogen.

Though development has recently slowed with the decline in oil prices, striking progress was made after 1983 in research and development of coal liquefaction technology in the United States, Japan, Germany, and Great Britain. Recent designs indicate that liquid fuels can be derived from coal at a cost equivalent to $35 (US) a barrel of crude oil, a level reached in the early 1980s.

In view of the enormous coal resources in North America and elsewhere, these technologies have the potential to provide a secure source of liquid fuels as an alternative to crude oil.

Ontario's lignite

Ontario does not have any bituminous coal resources, but it does have at least one large deposit of lignite, a soft coal with only half the heat value of bituminous coal. About 170 million tonnes of lignite (equivalent in energy to about four years' provincial coal consumption) exist in the Onakawana area in the James Bay lowlands. A number of proposals for developing this resource have been studied, but none has yet been economically attractive.

Ontario Hydro uses Saskatchewan lignite with a low sulphur content to fuel two units at the Thunder Bay generating station and one unit at Atikokan. Lignite could also be used to produce liquid fuels such as methanol.

Future coal potential in Ontario

As a source of energy for Ontario, coal is in reasonably secure supply. Western Canadian coal is generally lower in sulphur but not price-competitive with U.S. coal delivered to Ontario.

An intergovernmental committee is investigating ways of reducing the cost of producing Western Canadian coal and transporting it to the Ontario market. The committee has identified 14 projects for research, development, and precommercial demonstrations in the areas of mine productivity, coal product improvement, transportation, and regulatory changes. The estimates suggest that the greatest cost reductions could be achieved in transportation. A concept of transporting a coal-oil slurry mixture by pipeline could save an estimated $10-15 a tonne. Currently, the cost of rail and ship transportation accounts for about half of the $60 to $85 a tonne cost for Western Canadian coal delivered to Ontario.

The low-sulphur Western Canadian coal would have an advantage in another area of concern affecting all coal combustion, the issue of emissions. Provincial regulations limit the amount of acid gas emissions, mainly sulphur dioxide, from coal burned to generate electricity. Since 1976, Ontario Hydro has lowered the average sulphur content of its coal burn from 2.4 per cent to 1.2 per cent. Currently, Ontario Hydro is under an environmental control order to reduce its total acid gas emissions by about half from 1987 to 1994. Technologies which would make coal combustion cleaner are being developed. In Ontario the key short-term technology is flue gas desulphurization (scrubbers). For the longer term, attention is being directed at Integrated Gasification Combined Cycle (IGCC) technology and fluidized bed combustion.

Integrated Gasification Combined Cycle (IGCC)

When methane from natural sources first became commercially available it was called "natural gas" to distinguish it from the manufactured "coal gas" (mainly carbon monoxide and hydrogen) that had for decades been illuminating city streets with "gaslight". Coal gas and coal oil (kerosene) were among many by-products of the manufacture of coke, which is used in iron smelting. Coke is made from coal by destructive distillation or pyrolysis (heating in the absence of oxygen), the same way charcoal is made from wood.

The innovative IGCC technology generates electricity with high efficiency and low emissions. It brings together two concepts:

- *Combined cycles: a generator is driven by a gas turbine, whose exhaust then goes into a heat recovery boiler making steam to power a steam turbine linked to a second generator.*
- *Integrated gasification: the gas used to run the gas turbine is synthesized from coal. Heat recovery from coal gasification contributes additional steam to the steam turbine. Removal of contaminants from the syngas before it is burned in the gas turbine reduces the overall cost of emission control.*

Though still under development, IGCC offers several advantages over conventional technology:

- *thermal efficiencies better than conventional pulverized-coal plants*
- *lower sulphur and other emissions*
- *avoidance of costly flue-gas scrubbing and sludge disposal*
- *design flexibility because of modular components (size can be increased by adding units) and opportunities for phased construction*
- *operational flexibility because progressive start-ups and shutdowns are possible with low losses in efficiency and because natural gas can be used as an alternative fuel.*

Electricity

AROUND THE WORLD

Electricity accounts for 16 per cent of end-use energy consumption in the OECD countries. Most electricity generation around the globe is fossil-fired, but the generating shares of fossil-fuel combustion, water-power, and nuclear fission vary greatly among countries.

Electricity is much more important in the energy picture than its fairly small share of total consumption might suggest. Many of its uses are unique and, like electrical and electronic equipment, indispensable to modern economies. Demand is growing faster for electricity than for any other form of energy.

IN CANADA

Canada has an abundance of the primary energy resources normally used to generate electricity. Canada relies more on water-power and less on fossil fuels than most countries. Plentiful low-cost Canadian electricity has stimulated the development of electricity-intensive industries such as aluminum smelting, giving electricity a larger share of total energy consumption than is usual in developed countries.

IN ONTARIO

Almost all electricity in Ontario is generated by Ontario Hydro, whose capacity is broadly based in nuclear, hydro-electric and fossil-fired generation. With demand forecast to continue growing, important decisions on future supply and demand options are approaching.

AROUND THE WORLD

The main primary energy sources from which electricity is manufactured around the world are water-power (hence "hydro-electricity"), fossil fuels (the hydrocarbons: oil, natural gas, and coal), and nuclear fission. Fossil fuel generation and nuclear generation are sometimes classed together as "thermal" generation because they use steam.

Globally, electrical energy comes two-thirds from fossil fuels and only one-fifth from water-power. In Canada these proportions are reversed, with a two-thirds dependence on hydroelectric sources. In Ontario, however, the leading source is nuclear fission, which accounted for 47 per cent of the province's electricity generation in 1988. This share is about three times what it is in the world as a whole.

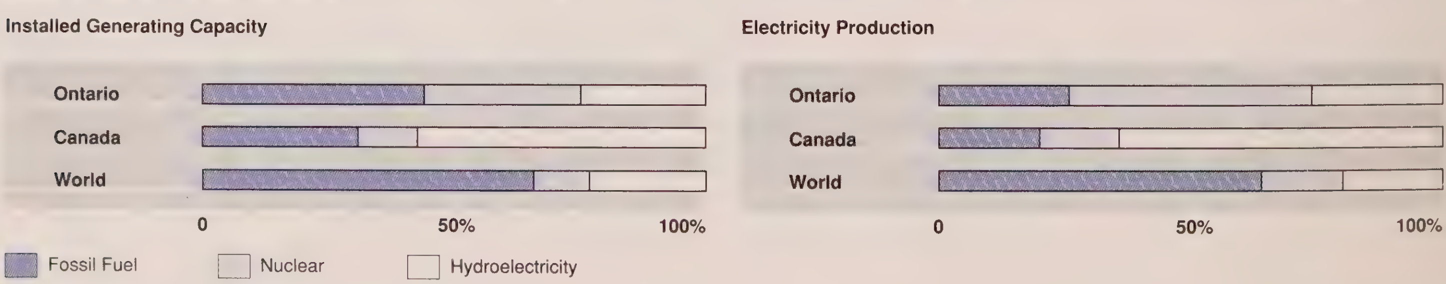
The growing reliance on nuclear power is a trend shown by many industrial nations. During the past two decades, world generation of electricity from nuclear power stations has grown dramatically, from 79 TeraWatt hours (TWh) in 1970 to twenty times that amount (1556 TWh) by 1986. Canada, France, the United States, Great Britain, Japan, West Germany, and the Soviet Union have developed significant nuclear power programs.

The world's consumption of electricity has more than tripled since 1965. The rate of growth has slowed somewhat since 1978, to an average 3.5 per cent a year, but electricity demand is growing faster than other energy forms.

To meet this demand, the total installed generating capacity globally at the end of 1986 was 2460 billion watts (gigawatts: GW). Two-thirds of this capacity was fossil-fired, one-quarter hydroelectric, and one-tenth nuclear. Fossil-fired and hydroelectric generation produced less energy than their shares of capacity (64 vs 66 per cent and 20 vs 23 per cent), while nuclear generation produced 16 per cent of total energy, though accounting for only 11 per cent of installed capacity. The reason is that nuclear generation, with its low fuel costs, is used to meet more constant "base loads", whereas fossil-fired and hydroelectric generation are more often

TYPES OF GENERATING CAPACITY AND ELECTRICITY PRODUCTION IN THE WORLD, CANADA, AND ONTARIO, 1987

Fossil fuel generation is prominent globally, hydroelectric in Canada, and nuclear in Ontario.



turned up and down to follow demand peaks and thus tend to operate at lower average outputs. Many hydroelectric plants are also limited by seasonal variations in water flow.

The giant electrical system of the United States, by far the world's largest, has 29 per cent of the world's total generating capacity.

GROWTH OF THE WORLD ELECTRICITY CONSUMPTION, 1965-1988

Source: Energy Statistics Yearbook, U.N., Various Issues

Year	World Consumption (TeraWatt hours)	Growth Rate Per Cent	Year	World Consumption (TeraWatt hours)	Growth Rate Per Cent
1965	3381		1977	7296	4.6
1966	3643	7.8	1978	7678	5.2
1967	3863	6.0	1979	7974	3.8
1968	4207	8.9	1980	8244	3.4
1969	4570	8.6	1981	8396	1.8
1970	4955	8.4	1982	8473	0.9
1971	5269	6.3	1983	8823	4.1
1972	5699	8.2	1984	9302	5.4
1973	6129	7.5	1985	9748	4.8
1974	6314	3.0	1986	10042	3.0
1975	6517	3.2	1987	10475	4.3
1976	6978	7.1	1988	10859	3.7

Energy, Power and Capacity

To see the difference between energy (the ability to do work) and power (the rate at which work is done), consider a 100-watt lightbulb. When switched on, this bulb performs work (consumes power) at the rate of 100 watts. But the amount of work it does (energy it consumes) depends on how long it burns: for example, in 10 hours it consumes 1000 watt-hours, or one kilowatt-hour (kWh).

To see the difference between power and capacity (rated maximum power), consider this lightbulb attached to a variable switch which is turned down to allow half the normal amount of electricity through. Now the bulb burns at 50 watts of power, though its capacity is still 100 watts.

The same principles apply to a generating station, except that instead of consuming energy it produces energy. A station's capacity may be 800 000 kilowatts, normally written as 800 megawatts (MW). At any moment of operation it may be producing power at its rated capacity of 800 MW or at some lower level – down to and including zero if it is shut down. The energy it produces in a week or a year is found by multiplying each successive power level by the time it was sustained. The result is a total production of kilowatt-hours (or megawatt-hours, or terawatt-hours, etc).

In electrical systems, therefore, all three concepts are important:

- *The capacity is the size of the system, determining the greatest load, or "demand", it can handle.*
- *The power is the amount of load, or demand, the system is handling at any moment.*
- *The energy is a sum over time of the amount of work done during that time by the system.*

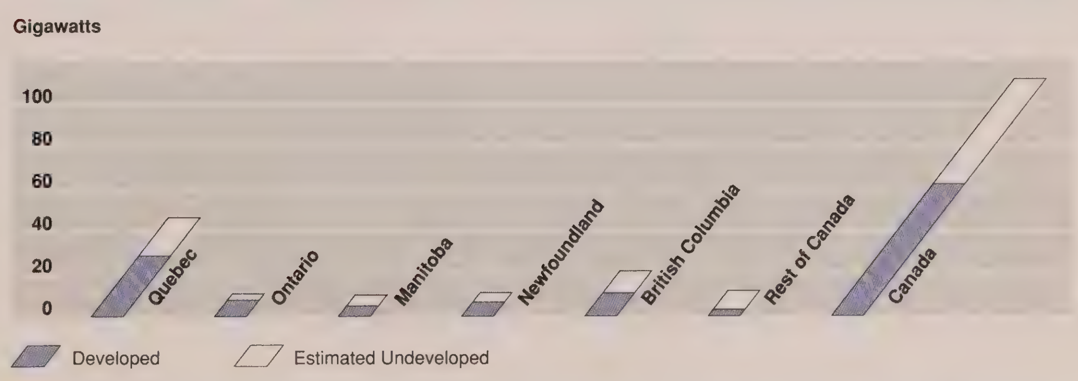
In statistical discussions one must distinguish carefully between references to capacity or power (watts, kW, MW, GW), which indicate equipment size and peak production, and references to energy (kilowatt-hours, MWh, GWh, TWh), which indicate quantities produced over stated intervals of time.

IN CANADA

Hydroelectric capacity, with 58 gigawatts in place, accounts for the largest part of Canada's total installed electrical generating capacity of 100 GW. The country's total hydroelectric potential has been estimated at 112 GW, of which almost half remains undeveloped. Over half of the undeveloped hydroelectric potential is in either Quebec (36 per cent) or British Columbia (21 per cent). Those two provinces and Manitoba are planning to build new hydroelectric generating

CANADIAN HYDROELECTRIC SOURCES, DEVELOPED CAPACITY AND ESTIMATED UNDEVELOPED POTENTIAL, 1987

Most of Canada's undeveloped hydroelectric potential is in Quebec and British Columbia.



ELECTRIC GENERATION AND CONSUMPTION ACROSS CANADA, 1988

Net electric self-sufficiency is the general rule for all provinces, with Newfoundland and New Brunswick being net exporters.

stations for export sales of electricity. Newfoundland also has substantial potential in Labrador. Because the best sites tend to get developed first, much of the remaining undeveloped potential will be expensive to realize.

In 1988, Canada consumed 94 per cent of the electricity it generated, exporting the rest to the United States. Among provinces, Quebec is the largest generator and consumer of electricity – generating 5 per cent more electricity and consuming 16 per cent more than Ontario. Newfoundland (through the Churchill Falls development whose power is sold to Quebec) and New Brunswick have the largest surpluses of generation over consumption. Between 1975 and 1988, Canadian electrical production grew by 80 per cent and consumption by 73 per cent. Electricity consumption grew faster than all the other end-use energy sources, at 4 per cent a year.

The Canadian electrical industry is dominated by publicly owned utilities which generated 85 per cent of the total electricity produced in 1988. Private utilities accounted for 7 per cent and industry for a further 8 per cent. Industry's share of electricity generation has been declining for many years.

IN ONTARIO

Supply

Ontario Hydro, a publicly owned utility, is responsible for almost all of the electricity generated in Ontario (94 per cent in 1988). The remainder is produced mainly by a number of large industrial companies supplying their own needs, and by private or municipally-owned electrical utilities.

The amount of electricity generated in Ontario grew by over three times from 45 TWh in 1965 to 143 TWh in 1988. Increased capacity allowed purchases from outside the province to fall. Although rising to 16 TWh in 1975, gross purchases declined to 5 TWh in 1988. Exports also increased so that, on balance, Ontario was a net exporter of electricity through the 1980s.

Another striking change over the last quarter-century has been the rise of new energy sources for generation. In 1965, Ontario's electricity generation was three-quarters hydroelectric and one-quarter coal-fired (nuclear power was negligible). By 1988, hydroelectric generation was higher in absolute terms but had fallen in share of total generation to about one-quarter. Similarly coal-fired generation, though it more than tripled in absolute terms since 1965, still accounted in 1988 for one-quarter of total generation.

The big difference was nuclear generation, whose share of total generation went from less than 1 per cent in 1965 to 47 per cent in 1988. Oil and natural gas generation had appeared in the interim, used mainly for peaking purposes, but were largely phased out after 1980 when the prices of these fuels rose. With the restart of the previously mothballed Lennox generating station, oil has reappeared for peak use.

Consumption

Since 1965 electricity consumption in Ontario has grown every year, but in three phases. From 1965 to 1974 consumption grew quickly at nearly 7 per cent annually. From 1974 to 1982 consumption grew much more slowly at just over 2 per cent annually. From 1982 to 1988 consumption growth picked up again to nearly 5 per cent annually, but even this high rate was lower than the 6 per cent annual growth over the same period in the booming Ontario economy.

Among the three major end-use sectors, the industrial and residential sectors have each increased their demand for electricity by about one-quarter since 1980, while commercial sector demand has grown even more, by about one-third.

In the *industrial* sector (38 per cent share of consumption), large users of electricity include pulp and paper, chemicals, and iron and steel firms. About two-thirds of industrial electricity use is in production processes, largely to operate motors.

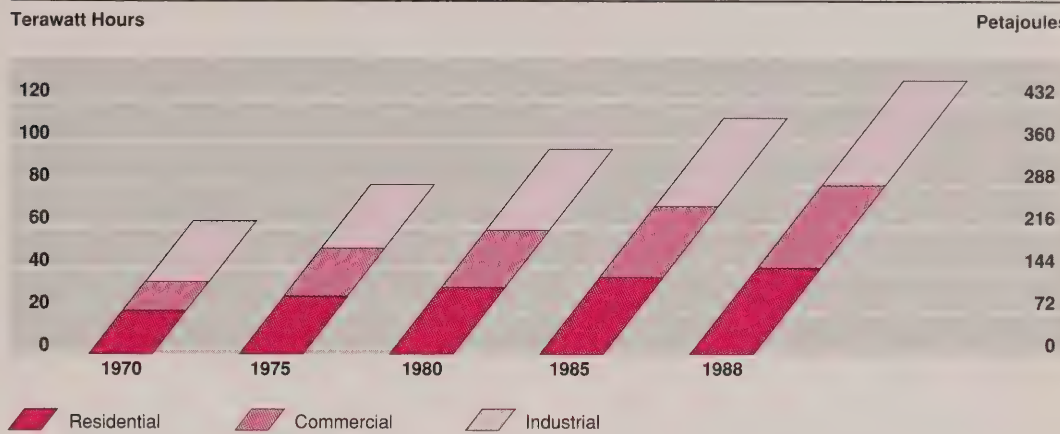
In the *residential* sector (32 per cent share), home heating and appliances such as refrigerators and freezers are the main uses, with lighting and water heating also being important. Air conditioning has a small but growing annual share (and a much higher actual share during periods of hot weather).

In the *commercial* sector (29 per cent share), the main uses are heating, cooling, and lighting of buildings such as offices, schools, hospitals, and stores. Less than 1 per cent of electricity is used in transportation, mainly for powering subways and streetcars in Toronto.

In January 1989 an all-time peak demand on the Ontario Hydro system of 23,068 MW was recorded, 2.1 per cent higher than in 1988. In the summer of 1989 an all-time summer peak of 20,103 MW was recorded, about 3 per cent higher than in 1988. In recent years the summer peak has become substantial in Ontario, in part because of the increased use of air conditioning and unusually hot summers.

GROWTH OF ONTARIO ELECTRICITY CONSUMPTION BY END-USE SINCE 1970

Electricity demand in Ontario has grown steadily in all three sectors.



Matching Supply and Demand

Electricity, alone among end-use energy types, must be used at the instant it is produced. Gasoline burning in an engine may have been manufactured weeks ago from crude oil taken from the ground months ago. But the electrical energy operating a television set is being manufactured as you watch it. The streetcar operator depressing his accelerator pedal may not realize that his action is increasing the load on some distant whirling turbine, tending to slow it ever so slightly.

Though individual uses balance out (so that for example when one streetcar is accelerating another is slowing down), overall use in a town or region has a daily, weekly, and seasonal cycle of higher and lower electrical use. To deliver the constant voltages and currents required by electrical equipment, the supply of electricity must always match the demand. Electricity must be generated just to the extent it is needed by consumers. Therefore Ontario Hydro must raise power output and start up additional generators during peak hours, days, and weeks, then as the peaks decline lower the power output and shut down the extra generators.

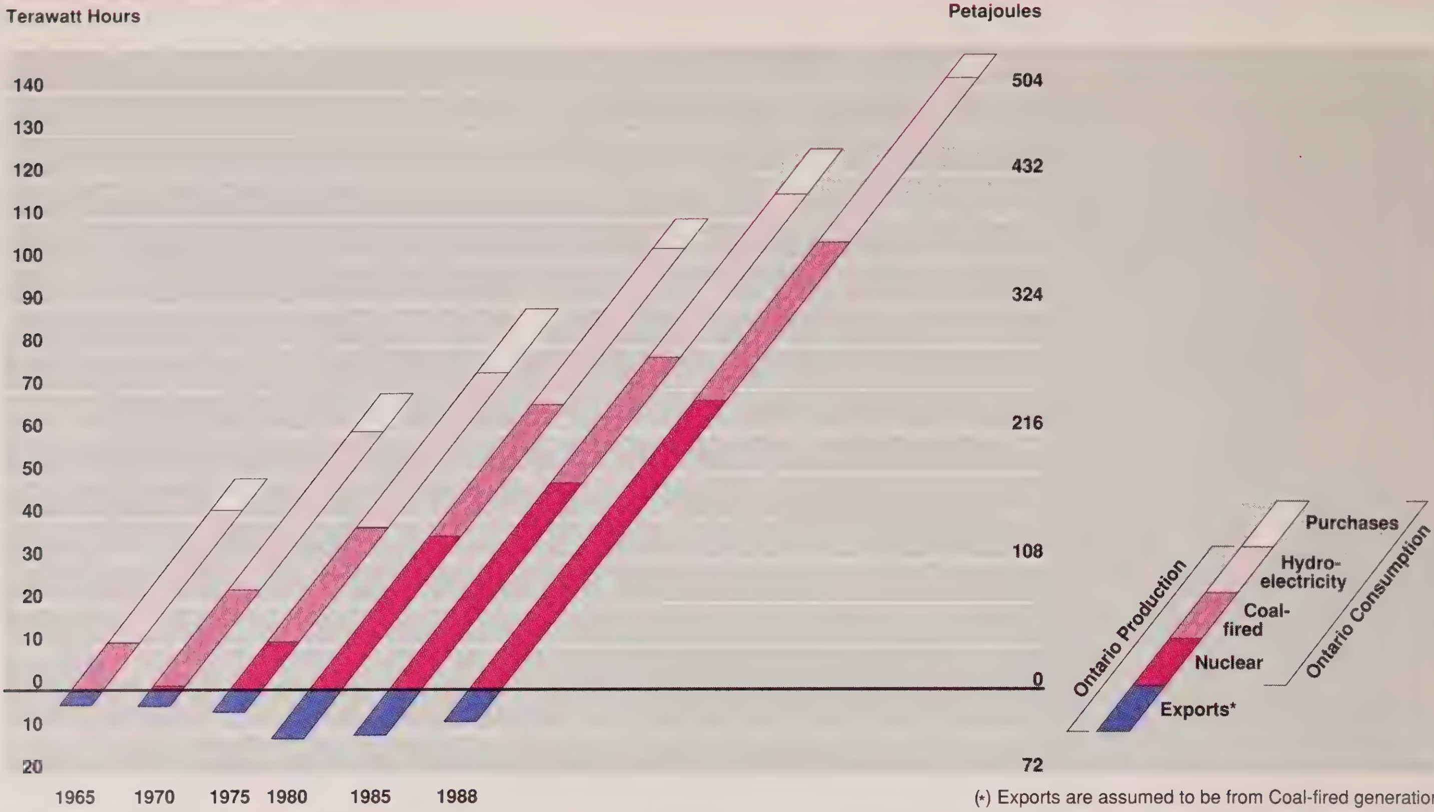
The total demand (required supply) in an electrical network can be divided between a "base load" that is always present and various "peak loads" representing intervals of heavier use. Peak loads are more expensive to meet than base loads.

The high costs of supplying demand peaks can be reduced by using types of generation more suited to lower capacity factors, that is, suited to irregular operation. Nuclear generation, in which power levels cannot efficiently be altered quickly, is best suited to base load supply. Coal-fired and oil-fired generation can be turned on, up, and down much more easily and so are used to meet peak loads. Hydroelectric generation can meet base or peak loads (depending on streamflow and reservoir capacity) and so in Ontario has a dual role.

Utilities such as Hydro also seek ways of reducing the ratio of peak loading to base loading. One way is to encourage the use of off-peak surplus capacity by offering lower prices for power in off-peak times. Another way is to sell "interruptible" power, which can be curtailed by the utility on very short notice at peak times, at a lower price than "firm" power, which cannot be interrupted over a given time except in emergencies. Measures such as these can reduce the need for generation to meet peak loads.

Ontario Hydro's transmission system

Ontario Hydro's transmission system consists of 27,000 km of circuits: over 2,200 km of 500 kV (kilovolts) circuits, 13,300 km of 230 kV, and 11,500 km of 115 kV. The grid extends from Quebec to Manitoba and from the United States to the James Bay lowlands. There are 232 transformer stations to step up the voltages for transmission, and 773 distribution stations to step down the voltage to a level suitable for use on Ontario Hydro's 103,000 km of distribution lines in the vicinity of towns and cities. Many more distribution lines are owned by the municipal electrical utilities.



GROWTH OF ONTARIO'S ELECTRICITY SUPPLY BY SOURCE

The growth of coal-fired generation in the 1960s and of nuclear power since 1970 has created a diversified base of primary sources in the 1980s.

Ontario Hydro is responsible for the generation and transmission of electric power and its sale to co-operating municipal electrical utilities. In most cities and towns, retail sales of electricity are the responsibility of a municipal electrical utility which owns and operates the municipal distribution system. Co-operating municipalities obtain their supply of power from Ontario Hydro at cost; in 1988, 316 municipalities were supplied with power.

Ontario Hydro also directly serves 836,000 rural retail customers and 106 industrial customers. Overall, in 1988 Hydro supplied 133 TWh of electricity to its customers, including secondary customers.

As demand grows, transmission systems must be enlarged and extended to deliver power to various parts of the province. Two major transmission projects are under way in Ontario. The Eastern Ontario project, connecting Ottawa to Kingston to Cornwall, and the Southwestern Ontario project, to deliver electricity from the Bruce generating station, are scheduled to be in service in 1991.

New transmission facilities will be required to serve the growing markets and load centres of the Golden Horseshoe area of southern Ontario. If large purchases were to be made from Quebec or Manitoba, major new transmission lines would also be needed.

Ontario Hydro's generating system

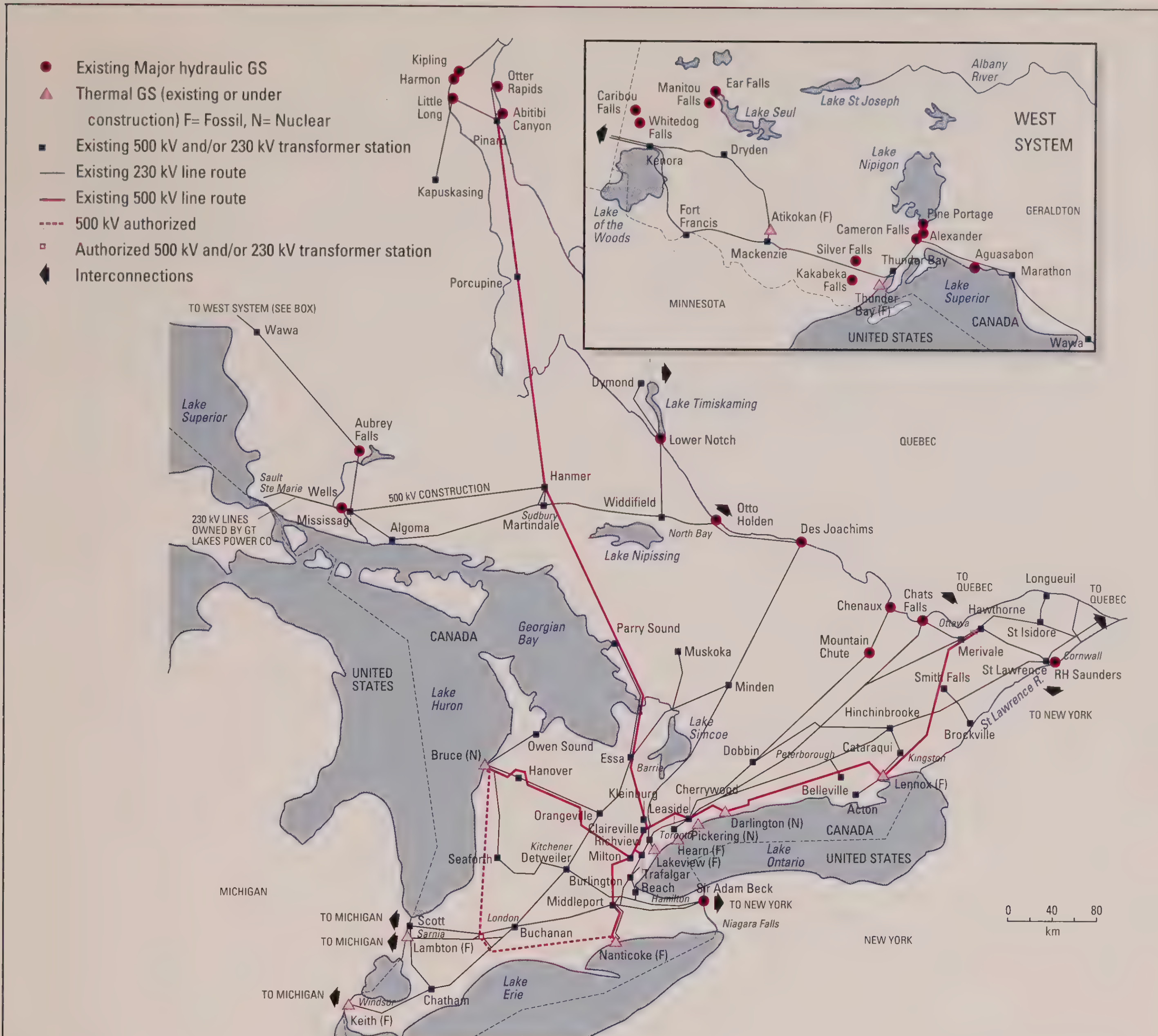
Ontario Hydro has the second largest generating system in Canada after Hydro Quebec. Total generating capacity is 30,100 MW, affording a reserve capacity of about 25 per cent over the peak demand, after allowing for interruptible demand and mothballed stations.

Hydroelectric

Hydroelectric power accounts for almost one-quarter of the capacity of Ontario Hydro's generating system. The peak hydroelectric capacity is 6500 MW, with an average generating capability of about 4400 MW. As Ontario Hydro's name suggests, hydroelectric generation was the original basis of its system, beginning with De Cew Falls, the first generating station built on the Niagara River, which began delivering power in 1904.

There has been no large-scale (greater than 20 MW) hydroelectric site development in Ontario since the early 1970s after the completion of stations at Aubrey Falls on the Mississagi River and Arnprior on the Madawaska River. Most of the province's undeveloped hydroelectric sites are in more remote areas and will be more expensive to develop. Variable water levels causing low capacity factors, environmental impacts, and concern for the effect on the lifestyle of native peoples are other impediments to the building of further hydroelectric stations.

Preliminary investigations of 17 northern Ontario sites have been conducted, which indicate a potential of 2000 MW of dependable peak power and an average annual energy of 550 MW. In 1985, Ontario Hydro approved further studies of development of the Niagara, Little Jackfish and Mattagami rivers. These three sites could add over 1000 MW of peaking capacity to the system during the 1990s.



ONTARIO HYDRO'S GENERATING SYSTEM

Nuclear generation is used increasingly for base load and hydroelectric and fossil-fired generation for peak loads.

Source: Ontario Hydro, Demand/Supply Plan

An Ontario Hydro program to upgrade existing hydroelectric plants by refurbishing generators and turbines began in 1974. By 1986, 46 units were refurbished, adding 186 MW of dependable peak capacity to the electrical system. Private development of small hydroelectric sites, through attractive buy-back rates and flexible financing of interconnection charges, is being encouraged by the Ontario government.

Nuclear

Nuclear power represents 35 per cent of Ontario Hydro's existing generating capacity. There are 16 reactors operating in Ontario: eight at the Bruce Stations on Lake Huron (6470 MW) and eight at Pickering to the east of Toronto (4120 MW). Four more reactors (3520 MW) are under construction at Darlington. When the Darlington station is completed in 1992, nuclear generation will account for 40 per cent of Ontario Hydro's installed capacity and provide over 60 per cent of the electricity generated in that year.

Though Ontario Hydro's nuclear reactors have excellent safety and operating records, the CANDU design requires replacement of pressure tubes during the reactors' lifetimes. Replacement of corroded pressure tubes in two Pickering reactors began in 1983 and was completed in 1988. Two reactors at Bruce will also need retubing before the end of the century. Nonetheless, two recent reports by reviewing teams of outside experts have confirmed both the low cost and the safety of Hydro's Candu reactors.

Canada has 10 per cent of the western world's known reserves of uranium, the fuel of nuclear reactors. Significant deposits exist in the Elliot Lake and Agnew Lake areas of northern Ontario, and there are even larger reserves of a richer grade ore in Saskatchewan. On average,

more than 80 per cent of Canada's annual uranium production is exported. To safeguard Canadian interests, the federal government requires that enough uranium be reserved to operate each existing and planned Canadian reactor for 30 years.

In 1988, Ontario Hydro purchased about 1400 tonnes of uranium: 70 per cent from Elliot Lake and 30 per cent from Saskatchewan. During the 1970s more uranium was contracted for than will probably be needed, so Ontario Hydro is forecasting a substantial annual oversupply for several years.

Coal and oil and natural gas

Ontario Hydro operates five coal-fired generating stations ranging in size from 200 MW to 4300 MW and accounting for about 32 per cent of its total generating capacity. The three largest stations are Nanticoke, located on the shore of Lake Erie, Lambton near Sarnia, and Lakeview station in Mississauga. Two older fossil-fired stations – the Keith station at Windsor and the Hearn station in Toronto – have been mothballed. Lennox, Ontario's only oil-fired station, was mothballed in 1980 because of high oil prices, but in 1987 Lennox's four 560 MW units began to be restarted to provide occasional peak power, and the whole station will be operating again in 1989.

Cost of Power from Different Sources (Ontario Hydro, 1988)

	Energy Production (TWh)	*Average Cost* (¢/kWh)
Nuclear	67.5	3.2
Hydro-electric	35.1	0.9
Fossil-fired	34.7	3.7
	137.3	

Ontario's long-established hydro stations provide the lowest cost power; nuclear power is less expensive than coal-fired power.

Acid gas control

Operation of coal-fired stations is constrained by Ontario's acid gas emission regulations. Coal burned to produce electricity is responsible for 20 per cent of all the acid gas emissions produced in Ontario, thus contributing to the environmental damage caused by acid rain. To protect the environment, government regulations limit the amount of sulphur dioxide and nitric oxide that Hydro's fossil-fuel stations can emit. Emissions of sulphur dioxide must be progressively reduced from 430 kilotonnes allowed in 1987 to 175 kilotonnes beginning in 1994. After 1993, emissions of sulphur dioxide and nitric oxides must not exceed, in the aggregate, 215 kilotonnes.

Ontario Hydro is pursuing three approaches to reduce acid gas emissions: burn less coal; use coal with a lower sulphur content; and install technology that will clean the coal and the combustion emissions.

Scrubbers will be installed in two out of four units of Lambton station and later in the other units to remove sulphur oxides from the flue gas. Special burners will be installed in some units at the Lakeview station to reduce nitric oxide emissions. Not only will Hydro seek to use an increasing proportion of low-sulphur coal, but also the amount of high-sulphur American coal burned will decline as the total amount of coal used is reduced and other sources replace coal-fired generation. For example, the annual electrical output of one Bruce nuclear reactor is equivalent to about 1.3 million tonnes of coal burned. Conservation and demand management also will reduce the need for coal-fired generation.

Additional commitments

In mid-1989, Ontario Hydro's only committed supply enhancements are the Darlington nuclear generating station expected to be in service by 1992 and a firm purchase of 200 MW from Manitoba to be delivered from 1998 to 2003. Studies for two proposed hydroelectric projects are under way: the Little Jackfish development near Lake Nipigon (132 MW peak) and the upgrading of four stations on the Mattagami River near Kapuskasing (398 MW peak), both to become available in the mid 1990s. Another possibility is to build a third station at the Beck site on the Niagara River (565 MW peak, 129 MW average).

Parallel generation

Parallel or independent generation is the generation of electricity by equipment that is owned and operated by a party other than a utility and is connected to the electricity grid. At present about 1200 MW of electrical capacity is privately operated in Ontario – 650 MW of hydroelectric and 517 MW of fossil fuel (mostly but not all gas). Most of this is used exclusively to serve the owner's own load, with the surplus sold to Ontario Hydro. An additional 1000 MW of power from parallel generation has been targetted by Ontario Hydro before the year 2000. Larger amounts up to 2000 MW are likely available by this date and are encouraged by government policy.

Potential parallel generation technologies include cogeneration, small hydro, and energy

from waste (EFW). Cogeneration – the simultaneous production of electricity and useful thermal energy (steam, hot liquids, or gases) from a single energy source – is perhaps the most promising form of parallel generation. Cogeneration is most often installed by large industries (pulp and paper, chemicals, etc.) that use the thermal energy for industrial process heat. Implementable potential for cogeneration is between 1300 and 3000 MW by the year 2000, the majority of which would be fired by natural gas. The potential for water-power is 150 to 200 MW, while energy from waste (including wood waste) is likely in the range of 100 MW. There are also proposals for large electricity generation projects, including stand-alone gas-fired plants, and generation at compressor stations on the TransCanada gas pipeline.

In Ontario, the private sector has taken a strong interest in small hydro. Several feasibility studies, demonstration projects, and privately financed developments have been completed.

Demand Management

Faced with growing demand and the costs of new supply, Ontario Hydro, like many electric utilities, has turned to managing the demand for electricity in order to meet future needs. Methods include encouraging more efficient use of electricity, purchase of more-efficient equipment, and shifting demand away from peak periods. Conservation and increased efficiency is the Ontario Government's first priority for meeting future needs. In response, Ontario Hydro has set a target for conservation that would slow the expected demand growth by 3,000 MW up to the year 2000, by means of financial incentives to customers. This is one-third of the projected increase in peak load growth that would otherwise occur. To achieve this target, Ontario Hydro will spend around $3 billion over the next decade. Information and financial incentives will be offered to electricity users in every part of the economy – including homeowners, commercial building operators and industries – to encourage them to use electricity more wisely and install more efficient equipment.

Ontario Hydro as a supplier of heat

Electrical generating stations provide heat in the form of waste steam or waste water that could be used in Ontario for agricultural, aquacultural, and industrial purposes. The Bruce Energy Centre, an industrial development located near Kincardine, Ontario, uses surplus steam from the Bruce nuclear station in industrial processes and for food production in greenhouses. Ontario Hydro supplies the steam at special incentive rates. Steam is also piped to the Bruce Heavy Water Plant to be used in the production of heavy water, which is used as the moderator in CANDU reactors.

Purchases and exports

In 1988, purchases of $57 million worth of electricity from neighbouring utilities provided 1.5 per cent of the total energy to Ontario Hydro's system. Purchases are made when it is economical to do so and during peak demand periods.

Further purchases could be made from Ontario's neighbouring provinces. Quebec's undeveloped hydroelectric resources amount to 17,900 MW. Quebec is planning to develop new capacity on the James Bay watershed, and is seeking firm buyers outside the province. Manitoba's resources are placed at 5100 MW and there are plans in place to develop sites on the Nelson and Churchill rivers, including the 1300 MW Conawapa site. Newfoundland hopes to develop 4500 MW on the lower Churchill River in Labrador, which would require transmission through Quebec to Ontario or U.S. markets. However, the growing American market for electricity exports may influence the availability and price of Ontario's potential purchases from these provinces.

In 1988, Ontario Hydro exported 5 TWh of electricity, primarily to U.S. utilities, for revenues of $156 million. Throughout the 1980s, Ontario was exporting large amounts of power to the United States, and revenues from these exports helped reduce electricity prices in Ontario by about 5 per cent on average.

Energy Prices

World oil prices strongly influence all energy prices. In Canada, the removal of government price controls, combined with the 1986 drop in wholesale oil and natural gas prices, has made oil and gas markets quite competitive. Retail price levels are less volatile because they include the costs of delivery and taxes. Canada's and Ontario's energy prices are among the lowest in the world.

WORLD OIL PRICES

In 1986 world oil prices fell from the high levels of the previous decade. Those high levels had been attained by the Organization of Petroleum Exporting Countries (OPEC) in two abrupt price increases in the 1970s: in 1973 with the Arab oil embargo and in 1979 with the Iranian revolution and the Iran-Iraq war. By the early 1980s oil prices maintained by OPEC averaged $30-34(US) a barrel and occasionally exceeded $40.

These unprecedented prices induced the expansion of new sources of oil supply, such as the North Sea and Mexico; they contributed to inflation and recession in industrial countries; and most important of all they encouraged massive conservation of oil in all countries and in every end-use as well as a switch to other types of energy. By incurring these responses, some observers have said, the oil price hikes were self-destructive.

From 1980 to 1985 declining demand and increased supply exerted increasing downward pressure on oil prices. OPEC reacted by gradually decreasing production, slowing the price decline though not eliminating it.

By the mid-1980s some members of OPEC, in particular Saudi Arabia, had come to regard the price of oil as too high for their own long-term interests. In the fall of 1985 Saudi Arabia took the initiative against other producers by increasing its production, from the low level that had helped maintain prices up to its full entitlement under the OPEC quota system, and by abandoning fixed prices. As this excess supply began to reach markets towards the end of 1985, oil prices first softened then plummeted. By mid-1986 they had dropped from about $28(US) to around $10 a barrel.

The chaos among oil producers caused by the Saudi initiative resulted in a new OPEC agreement that took effect at the beginning of 1987. New, lower production quotas were established, along with mechanisms to adjust production levels periodically to maintain an average price of $18 a barrel. But in 1988 OPEC members again began producing above quota, driving down prices and leading to a new agreement in December 1988.

In 1989 oil prices recovered again because of several influences: a surge in world oil demand, the first-ever agreement on limiting production between some non-OPEC countries, and the declining American oil supply. Nevertheless, OPEC overproduction and new supplies from non-OPEC sources continued to restrain oil price increases.

CANADIAN OIL PRICES

In Canada, crude oil prices were controlled by governments from 1973 to 1985, which caused them to rise more slowly than world prices. This regulatory arrangement kept prices for consumers and industries at or below the levels paid by competitors in the United States, where oil prices were also government-controlled.

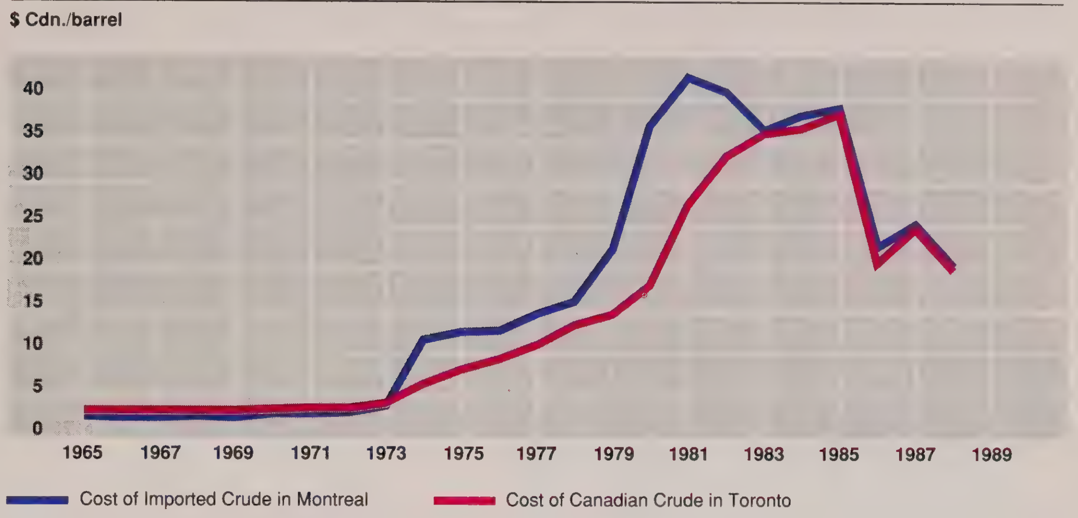
At first oil prices had increased in stages as agreed from time to time between the federal and producing-province governments. This federal-provincial system of oil price controls came under pressure in the early 1980s. The National Energy Program of 1980 and the Canada-Alberta

Agreement on Energy Pricing and Taxation of 1981 were attempts to reconcile diverging federal and provincial interests. As world oil prices declined from their peak after 1982, amendments to the price control system made it increasingly rigid and complex. By early 1985 Canadian oil prices exceeded world prices.

In June 1985, Canadian oil prices and markets were de-controlled. The Canada-Alberta Agreement was cancelled, and Canadian oil prices began to vary with world prices. Since then, in practice Canadian oil prices have been determined in two key markets: Chicago, where Canadian oil competes with American and other crudes, and Montreal, where it competes with imported oil from the North Sea, South America, Africa, and the Middle East.

CANADIAN CRUDE OIL PRICES 1965-88

Canadian crude oil was cheaper than imported crude oil in Canada for a decade after 1973, though prices of both were rising sharply.



Under deregulation, Canadian crude oil prices have closely followed international prices, with allowance for the cost of transporting the oil to the market. Both Canadian and international crude prices dropped nearly in half between 1985 and 1986. Canadian oil consumers thus benefitted through lower retail prices for gasoline, diesel, and heating oil, although this has been partly offset by increased taxes and by higher margins on refining and sale of these products.

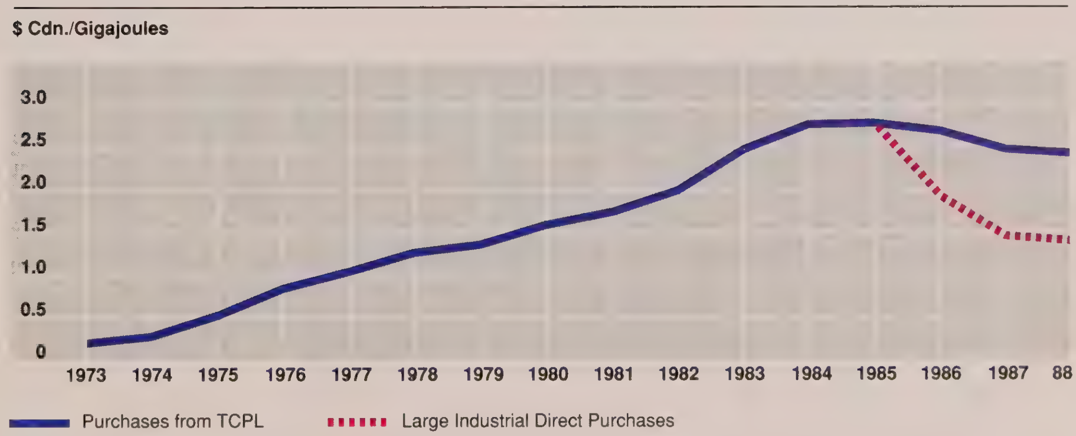
CANADIAN NATURAL GAS PRICES

Until 1985 the price of natural gas, like the price of oil, was controlled by government. The federal government's move to price deregulation that year led to the October 1985 Agreement on Natural Gas Markets and Prices between the federal government and the three westernmost provinces. The Agreement introduced a market-oriented regime for both domestic and exported natural gas. It allowed customers whose contracts expired to negotiate new contracts directly with natural gas producers, and allowed the gas distribution companies to offer price discounts to meet competition. Moreover, beginning one year later, in November 1986, the wholesale price of all gas sold in interprovincial trade, including that sold by TransCanada PipeLines to the distribution companies, was to be freely determined by negotiation between buyers and sellers.

TransCanada PipeLines moves gas eastwards from Western Canada to both domestic and foreign markets, levying transportation tolls which are regulated by the National Energy Board. Most of the gas is bought by the gas distribution companies for resale to their smaller customers

ALBERTA BORDER PRICE FOR NATURAL GAS 1973-88

Wholesale prices for Canadian natural gas have followed much the same pattern as oil prices, showing the latter's influence.



under agreements with Western Gas Marketing Ltd., a subsidiary of TransCanada PipeLines. Distributors can also purchase incremental volumes from producers in Alberta, Saskatchewan and the United States.

Although not a signatory to the 1985 Agreement, Ontario moved quickly to encourage development of a competitive gas market in areas under its jurisdiction. For example, users gained the right to contract with distribution systems in the province for gas transportation. The three large Ontario distributors – Consumers' Gas, Union Gas, and ICG Utilities – now provide larger customers with a range of purchase options, from a single price for gas including all distributors' services, to an "unbundled" price where separate charges are made for gas, transportation, storage, seasonal load-balancing, and other services.

In Ontario the main beneficiaries of deregulation to date have been large industrial customers. In 1988, they were able to purchase gas at an average user price of $2.41/GJ, versus $3.87/GJ three years earlier. Small volume customers have also benefitted from lower prices, though not to the same extent.

The retail price of natural gas for customers in southern Ontario normally has three major components: the distribution charges (covering the costs of transmitting, storing, and distributing, incurred within Ontario by the gas distributor), the transportation tolls paid to TransCanada PipeLines, and the Alberta border price (for gas purchased in Alberta). The Alberta border price includes the revenue to the gas producer, the gathering costs on the NOVA pipeline system and other costs regulated by Alberta.

COMPOSITION OF RETAIL PRICE OF NATURAL GAS FOR SOUTHERN ONTARIO RESIDENTIAL CUSTOMERS (ALBERTA PURCHASES 1988)

Delivery from wellhead to consumers can account for almost two-thirds of the cost of natural gas in Ontario.

	$/GJ
Cost of Gas	1.98
Gathering costs of Nova	0.21
Processing, gathering and Topgas charges	0.25
Alberta Border Price	2.44
Transportation on TransCanada PipeLines	0.77
City Gate Price in Ontario	3.21
Distributors' charges for transportation, storing and distributing	2.39
Average Retail Price to Residential Customer	**5.60**

In Ontario the retail gas prices charged by distributors are regulated by the Ontario Energy Board. They vary widely between types of users largely because of different levels of distribution costs, which range from about $2.40/GJ for small residential customers to about $0.30/GJ for large industrial firms.

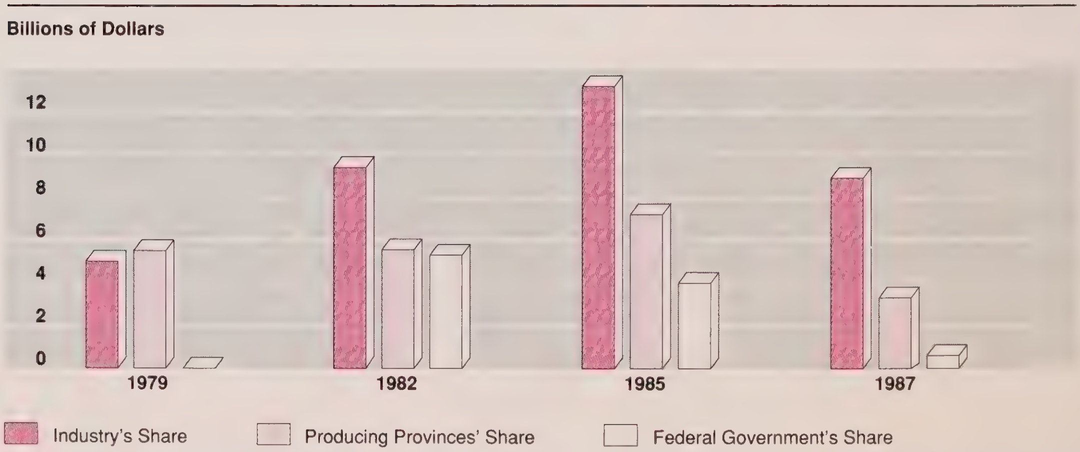
DIVISION OF OIL AND NATURAL GAS REVENUES

The sale of oil and natural gas provides both sales income for the energy industry and tax and royalty revenues for the federal and provincial governments. The proportions of this division were a central concern of energy policy in Canada in the early 1980s, when the issue was how to share rapidly rising incomes. Since the 1986 fall in prices, both federal and provincial governments have reduced their revenues at the production end to assist oil and gas producers. However, federal taxes on gasoline and diesel fuel at the pump have increased. The federal excise tax on gasoline has risen from 1.5 cents a litre in 1984 to 7.5 cents in 1989.

At the wholesale or "upstream" level, revenues have changed dramatically in the 1980s. Total wholesale revenues for oil and gas rose from $11 billion in 1979 to $24 billion in 1985 then dropped suddenly to $12 billion in 1986. The decline severely cut both cash flow to the industry

DIVISION OF WHOLESALE CRUDE OIL AND NATURAL GAS REVENUES, 1979-87

The Governments' share of upstream oil and gas revenues have fallen since 1985.



and royalty and tax receipts to the federal and producing province governments.

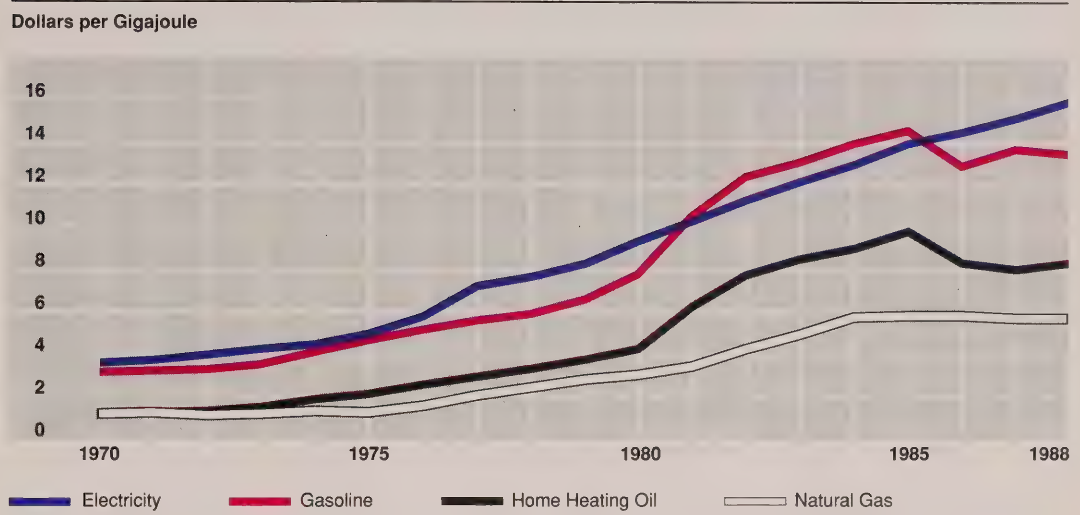
At the retail or "downstream" end, tax rates vary between products. In Ontario, gasoline and diesel fuel are taxed by both governments, but heating oil, natural gas and electricity are tax-free. This situation will change in 1991 if the federal government's proposed goods and services tax is introduced. Under current proposals, a 7 per cent tax would be charged on most goods and services, including heating oil, natural gas and electricity.

ENERGY PRICES IN ONTARIO

Since 1970 oil and gas prices in Ontario have gone through two successive rises, first in 1973 and then more steeply in 1979, followed by a large drop in 1986. Electricity prices have changed less dramatically. They rose steeply in 1976-77 and more modestly since then, rising in line with the general rate of price inflation since the early 1980s. In current dollars, electricity and gasoline were more than four times as expensive in 1988 as in 1970, heating oil six times, and natural gas more than five times. However, current dollar amounts omit the effect of inflation, which since 1970 has increased all prices and reduced the value of a dollar by more than three times. Over this period, therefore, the increase in the real cost of energy to the consumer (in constant dollars) has been much more modest.

ONTARIO RETAIL ENERGY PRICES, 1970-88

Retail energy prices follow the same pattern as the wholesale prices on which they are based.



Electricity

In Ontario electricity is priced on the principle of power at cost. Ontario Hydro sets its bulk power rates (the rates charged to municipal utilities and large industrial direct customers), after review by the Ontario Energy Board, to cover its costs of capital, fuel, operations, and administration, and its net income. The bulk power rates to municipal utilities also cover the costs of Hydro's bulk transmission system. The municipal utilities themselves in their own rates cover the costs of distributing power to individual end-users.

Retail rates vary slightly between municipal utilities, with an average cost to residential customers in 1988 of 5.8 cents per kilowatt-hour. The average cost to large industrial customers served directly by Ontario Hydro was 3.8 cents/kWh.

In 1989 Ontario Hydro introduced time-of-use rates to reflect the higher costs of supplying electricity at peak times of day and during the winter. For large industrial customers the winter peak rate is 18 per cent higher than the summer peak rate and 70 per cent higher than off-peak winter rates. Municipal utilities have the option of choosing whether to adopt time-of-use rates. For residential customers the payment of different prices at different times of uses will depend on the introduction of suitable metering equipment.

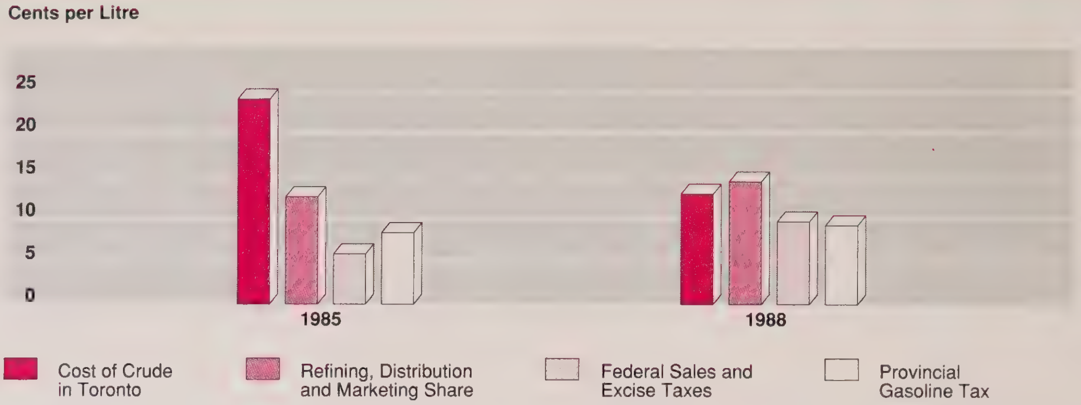
Gasoline and diesel fuel

Gasoline and diesel fuel prices reflect the costs of crude oil production, refining, marketing, retailing, and taxes. From 1985 to 1988 the cost of crude oil to the refiner fell by about 11 cents a litre. However, at the same time on gasoline the return to the refiner and dealer rose by about 2 cents a litre, federal taxes rose sharply by 4 cents a litre, and provincial taxes rose slightly. Therefore, retail gasoline prices fell by only 5 cents a litre. Gasoline prices are generally higher in Northern Ontario, due to smaller markets and higher costs. Automotive diesel prices have remained almost unchanged since 1985.

To encourage the use of alternative transportation fuels, the Ontario and federal governments exempt natural gas and alcohol fuels for automotive use from the excise taxes levied on gasoline and diesel fuel. Propane also benefits from much lower taxes. Automotive propane prices averaged 28 cents a litre in Ontario in 1988.

COMPONENTS OF GASOLINE COST IN TORONTO, 1985 AND 1988

Retail gasoline prices have changed little since 1985, because the lower cost of crude oil has been offset by higher federal taxes and higher refining/marketing margins.



Residential

To heat their homes, many homeowners can choose between natural gas, oil, and electricity. In 1988 the relative prices for equivalent energy units were as follows: natural gas $5.60/GJ, heating oil $8.40/GJ, and electricity $16.00/GJ. Even when allowance is made for the higher efficiency of electric heating, natural gas remained much less expensive than oil or electricity in 1988. In fact, a gas furnace was more cost-effective than the most efficient electric facility (a heat pump).

Industrial and commercial

After the large energy price increases of the 1970s and early 1980s, large industrial firms have benefited from sharply lower oil and natural gas prices since 1985. Heavy fuel oil prices fell from 19.2 cents a litre in 1985 to 10.8 cents a litre in 1988, while industrial natural gas prices fell by 38 per cent from $3.87 to $2.41/GJ. From 1985 to 1988, electricity prices rose 14 per cent, roughly in line with inflation.

Energy prices for commercial users have followed the same pattern, except that the recent fall in natural gas prices has been less than for industrial users.

Comparison to other jurisdictions

Ontario residents benefit from some of the lowest energy prices found in any developed nation. Plentiful Canadian energy resources and an efficient Canadian energy industry are major factors. Lower tax rates contribute as well: taxes on gasoline and diesel fuels, for example, are much lower than in other industrial countries except the United States.

ELECTRICITY RATES IN SELECTED NORTH AMERICAN MUNICIPALITIES, 1988

Electricity prices in Ontario are very competitive.

Electricity rates for Ontario residents and industries continue to be lower than those in most places in North America. In Canada, rates are lowest of all in Manitoba and Quebec, where large hydro-electric plants supply nearly all the power. But Ontario rates are about one-half or less the

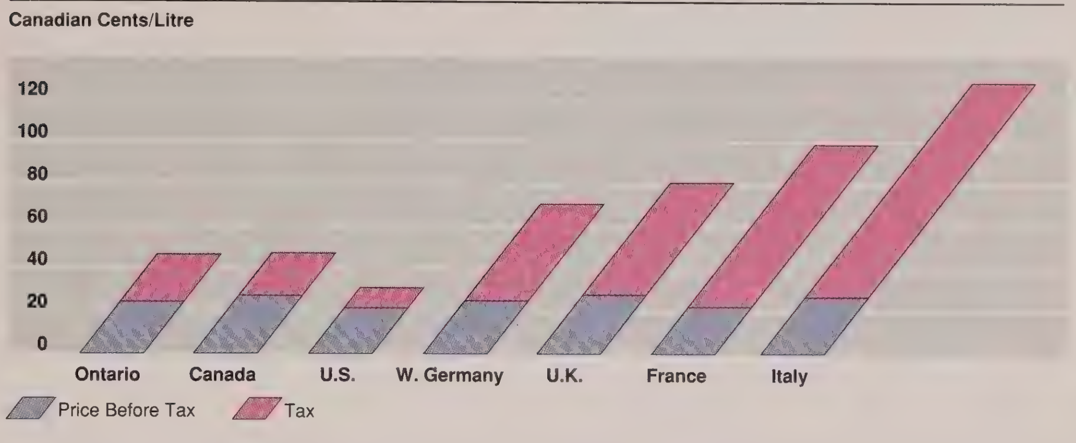
amounts common in large American cities. Such low prices help give a significant economic advantage to Ontario consumers and businesses.

For *gasoline,* the United States, lowest in both refined cost and retail taxes among the countries shown, has the lowest prices. In Europe, retail taxation of gasoline is much higher, ranging from nearly two-thirds of the price in West Germany to four-fifths of the price in Italy. Canada, with a refined cost comparable to those in Europe, has a significantly lower gasoline price because retail taxes are far lower, just over two-fifths of the pump price.

For *heating oil,* Canada has the fourth lowest prices because heating oil is not taxed at retail. West Germany, with a low manufactured cost and a moderate retail tax level, has the lowest prices. Once again, the highest retail tax regime is in Italy (more than three-fifths of the price).

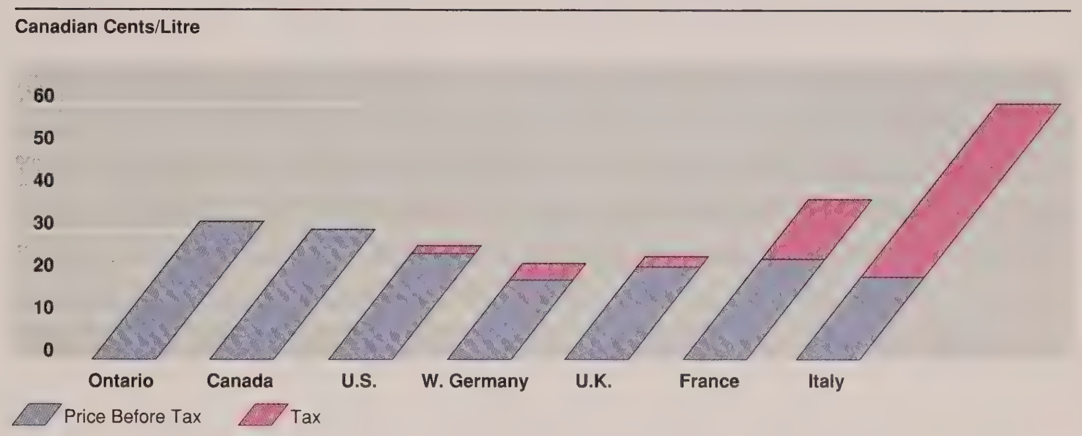
GASOLINE RETAIL PRICES IN NORTH AMERICA AND EUROPE, 1988

Gasoline retail price levels are heavily influenced by tax rates, which in Europe are much higher than in North America.



HOME HEATING OIL RETAIL PRICE COMPONENTS IN NORTH AMERICA AND EUROPE, 1988

Tax rates on home heating oil are low in most countries, though not all. Canada imposes no tax at all.

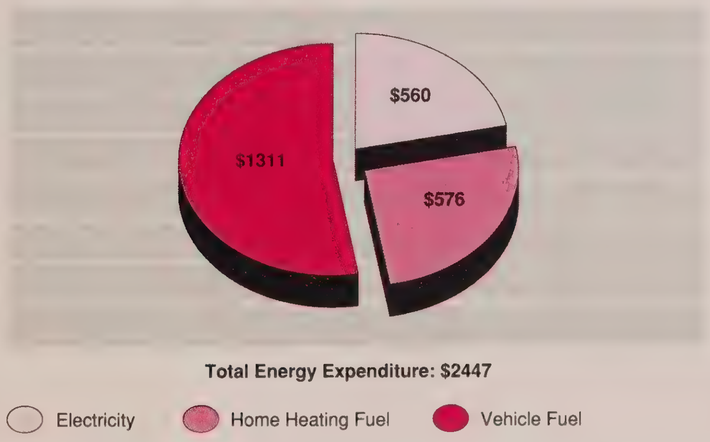


Family expenditures on energy in Ontario

The average Ontario family spent nearly $2500 on energy in 1986, about 6 per cent of total expenditure. Energy use was of two kinds: in the home and for transportation. Slightly more was spent on vehicle fuel ($1,311) than on all energy use in the home ($1,136). The latter was split almost evenly between electricity costs (including cost of electric heat for some families) and home heating fuel, most commonly natural gas.

ANNUAL ENERGY EXPENDITURE OF THE AVERAGE ONTARIO FAMILY, 1986

Energy use accounts directly for about 6 per cent of the annual expenditure of the average Ontario family, and of that more than half goes for vehicle fuel.



Renewable and Alternative Energy

Efforts are under way to reduce reliance on conventional energy sources by supplementing them with renewable and alternative energy technologies. In the early 1980s, when oil prices were on the way up, enthusiasm for unconventional energy alternatives ran high. In the late 1980s, with oil in abundant supply at lower prices, potential investors in unconventional options look more closely at payback periods.

OLD AND NEW ENERGY SOURCES

Each energy source in widespread use is surrounded by technologies on which it depends for production, distribution, and consumer use. With crude oil, for example, the oil industry provides exploration, drilling, production, transportation, refining and product distribution. Furthermore, consumers' use of oil involves an enormous investment in the automobiles, aircraft, furnaces, and other user technologies by which oil products are applied. Natural gas, coal, and electricity have similar technological infrastructures which allow them to provide energy services to the consumer.

The investments sunk in such vast infrastructures are what distinguish the "conventional" energy sources from unconventional ones and help make the former cheaper than the latter. Yet for every conventional energy source this broad investment base took decades to build, and for each there was an earlier time when it too was new, innovative, and struggling.

The rise of new energy sources in the past has not occurred because previous sources were becoming exhausted. Instead, the currently conventional energy sources spread through industrial economies because each made possible new technologies with certain decisive advantages over its predecessors. Coal was a much more concentrated energy form than wood and more easily distributed and stored. Oil was conveniently made into liquid fuels suitable for internal combustion engines and vehicles. Natural gas was more easily distributed (once a gas pipeline existed) and cleaner burning than oil products. Electricity not only created entirely new energy uses, from lightbulbs and appliances to computers, but also enabled them to be supplied from almost any primary energy source. Nuclear fission brought production advantages to thermal generation based on far higher energy source concentration and lower waste emissions.

There is no reason to believe that this long-term innovation process has come to an end. New areas of opportunity continually arise. Potential advantages to new sources and technologies can be in three areas:

- *Environmental impacts.* Growing evidence and concern about harmful results from fossil fuel use, which increasingly drive efforts at energy conservation and efficiency, at the same time afford opportunities for new energy technologies.
- *Fuel costs.* Production costs for oil, coal, and natural gas are expected to rise in the long term as the most accessible and most suitable deposits are consumed. Research into lower-cost alternatives will intensify.
- *Energy Security.* New energy technologies can diversify sources of energy supply and diminish the risks of over-reliance on a particular source or technology.

New energy sources and technologies with advantages in these areas will likely grow to supplement the existing established sources and technologies. They may gain early footholds in special market niches where they offer immediate benefits. There they may be developed further until a technical breakthrough or a change in external circumstances launches them more widely. (Solar photovoltaic cells and natural gas in urban buses are examples.)

Energy and Sustainable Development

The term "sustainable development" has entered common usage following the report of the United Nations World Commission on Environment and Development (the Brundtland Commission). This comprehensive global review of environmental and economic trends concluded that widespread irreversible damage to planetary ecosystems was beginning to result from the combination of wasteful resource exploitation and consumption in wealthy countries and poverty and scarcity in poorer ones. The report stressed the urgency of introducing new forms of economic development that the environment could sustain without permanent damage.

Canada and Ontario have responded to the Brundtland Commission's call for sustainable development by establishing Round Tables on Environment and Economy whose membership includes cabinet ministers, business and labour leaders, environmentalists, academics, and leaders of international organizations. The Round Tables will promote sustainable development principles throughout the economy.

Energy production and consumption technologies contribute substantially to global warming, acid gas emissions, stratospheric ozone depletion, urban smog, and ocean pollution. In the terms of the Brundtland Report, the conventional fossil fuel technologies in particular are unsustainable. The Report concludes that a low energy path is the best way towards a sustainable future. Otherwise, future generations will live on a seriously degraded planet.

To create and implement better energy technologies will require a large amount of public and private investment. The Brundtland Commission points out that such investment will be encouraged by a wider recognition of the true environmental costs imposed by current technologies. The environment provides important services to the private sector free of charge, such as waste removal by air and water or site accommodation despite disruption of natural habitat. Since these services are not purchased, they are not accounted for in investment decisions and do not signal resource depletion with price increases. Traditional costing principles are therefore misleading if they omit environmental effects. Principles that take account of environmental effects to establish true project costs are increasingly being used for decision-making on resource-related investments.

RENEWABLE ENERGY

The primary sources of conventional energy are natural *stores,* such as oil or gas reserves or coal or uranium deposits. In contrast, renewable energy is drawn directly from natural *processes* themselves, such as falling water, sunlight, tree or plant growth, in cases where their energy can be harvested and released for controlled application.

The renewable energy technologies with the greatest potential in Central Canada are based on water-power, solar, wood, wind power, and biomass resources. Elsewhere in Canada and around the world, tidal power and geothermal resources are also being developed.

Water-power

Electricity generation from falling water is by far the largest commercial source of renewable energy and is by no means a new technology. Though in widespread use around the world, vast further resources are available. Even in Canada, less than half the available hydroelectric potential has been developed, although future sites will be more expensive to develop. For decades Canada has been a world leader in large-scale hydroelectric technologies. In Ontario, over 7000 megawatts of hydroelectric facilities provide a quarter of electricity supply.

At the same time interest is growing in smaller-scale hydro developed by private entities. In many third world countries where villages are entering the television age before they can be reached by central power grids, local hydro installations provide a means of electrification. In developed countries, the option of rehabilitating old, abandoned sites and developing new small water-power plants can seem more attractive than massive investments in central facilities and transmission lines. Hydroelectricity avoids the environmental problems of fossil fuel combustion, but it can have impacts such as erosion, mercury leaching and flooding which should be considered in environmental assessments of hydro projects.

Since 1981, the Ontario government has been in strong support of private water-power development. The province has provided stimulus in the form of financial assistance and streamlining of legislation and approvals for water-power development. As a result of site feasibility studies and other incentives over 41 water-power sites (representing about 40 megawatts of new capacity) are currently under construction and over 120 megawatts of additional capacity have been committed.

Solar Energy

An international industry for "active" solar energy is growing steadily. Its main market appears to be systems for domestic and commercial hot water and for industrial process heat. In tropical countries many buildings requiring hot water already employ solar heating. Similar installations have yet to penetrate moderate climates but may do so to a limited extent over the next decade. Widespread use of active solar heating for residential space heating is unlikely because of costs.

"Passive" solar techniques are becoming common in developed countries for both heating and cooling in moderate climates and for cooling in southern climates (eg. rooftop evaporators).

Passive solar building designs can make significant improvements in buildings' energy efficiency. Canadian building designers are expert in adapting passive solar energy techniques and energy efficient designs to increase comfort while reducing the consumption of conventional fuels.

The attractiveness of active solar heating technologies is limited in Canada because of the northern latitude, which reduces solar radiation in colder seasons. But technology development continues and new market niches are developing. An example is the attachment of solar collectors to factory walls to preheat ventilation air in cold weather while reducing heat loss from the interior. Several factories in Ontario have installed such systems.

In Ontario, active solar energy systems are used mainly to heat swimming pools and to supply some industries with low-temperature heat. For instance, since 1982 a solar heating system has supplied hot water to a large laundry in the Niagara area. Some Ontario research in active solar systems is for applications of use in tropical countries.

Solar Energy Technologies

There are three kinds of solar energy technology:

- *Passive solar technology uses principles of design to accept or exclude the light and heat of the sun. In residential construction, southerly orientation, appropriate size and placement of windows, sunscreen blinds, overhangs, and awnings are examples of passive solar technology.*
- *Active solar technology traps and collects solar heat, transfers it by fluids, and often stores it. Solar hot water heating systems are an example.*
- *Photovoltaic technology converts sunlight directly into electricity in light-sensitive electric cells.*

The effectiveness of solar technologies depends upon the hours of sunlight available and its intensity.

Photovoltaic technologies have dropped rapidly in price over the last decade, with Japan as technology leader. A significant market in photovoltaic electronic calculators and radios now exists which is supporting further research and development. However, they may not live up to early optimistic predictions of large-scale photovoltaic electricity production because of the inherent diffusion of sunlight as a power source: the physical size of a solar cell array creates a formidable cost barrier for high power outputs. In Europe there are 2000 solar-powered small commuter cars powered by photovoltaic-cell-charged batteries.

Photovoltaic technologies for low-energy applications in remote locations are being demonstrated in Ontario. Despite their high capital cost and need for battery storage, photovoltaic technologies are attractive because they need little or no maintenance, a vital consideration in remote communications sites such as TV repeater stations. A 10 kW photovoltaic system, enough to supply several residences, is being demonstrated in the remote Ontario community of Big Trout Lake.

Wood

Wood is the leading source of energy for space and water heating and for cooking in developing countries and in remote areas of the developed world. However, wood energy is renewable only if regrowth is part of the energy cycle. In many developing countries wood energy use brings deforestation and continually increasing transportation distances for access to unused timber supplies. Over-reliance on wood for energy has become a massive problem for such countries with rapidly growing populations.

In developed countries the largest use of wood occurs in the forest-related industries, much of it being wood waste. Wood is also burned directly in industrial co-generation systems often in conjunction with district heating.

As the use of wood for energy purposes increases, new supplies will have to augment available waste. This may lead to the commercialization of energy plantations using fast growing tree varieties and under-utilized land. Trees can offer both energy supplies and reduction of atmospheric carbon dioxide.

Wood burning by the forest industries and domestically in remote areas is significant across Canada. Wood-burning stoves, fireplaces, and even furnaces are common in cottages and rural residences. But because of the distances required for its gathering, its preparation requirements (cutting and drying), and its smoke and ash residues, wood is likely to remain an auxiliary energy source, except in the forest industries. The pulp and paper industry uses spent pulping liquor and wood wastes extensively to co-generate process steam and electricity.

In Ontario, of the energy produced by wood burning, about four-fifths is in the forest products industry and one-fifth is in residential heating. This provides 3 per cent of Ontario's end use energy needs.

As an example of new technology, an innovative system for cogeneration by direct burning of pulverized wood in a gas turbine is being developed. A 5.5 MW version of such a system could be mounted on a trailer and moved between locations where biomass is collected.

Wind power

Wind-powered electrical generation also seems less promising than it did in the 1970s. At that time interest focused on huge, multimegawatt wind turbines. Demonstrations of these large technologies showed them to be in need of much further development. By the 1980s interest was shifting to smaller machines, which can be more easily integrated with an existing power supply and are more likely to prove economic in the short term because the technology is less risky.

Wind, like sunlight, is a diffused power source in most places at most times. Wind speed variations are magnified in power outputs, while intermittent winds make it necessary to install backup generation or large storage capacity. Nonetheless, in certain coastal or topographic situations where airflows tend to be strong, constant and uniform, favourable generating locations may be found.

In Canada, development of advanced wind turbine designs has occurred with government assistance, and demonstrations of new designs and increasingly reliable machines have been taking place at the Atlantic Wind Test Site in Prince Edward Island. However, the wind regime is not favourable to economic electric generation in most settled and industrial areas of Canada at present.

Wind Speed and Power

A difficulty with wind-powered electric generation is the fact that the power output of a wind turbine varies as the cube of the wind speed. The same is true of hydraulic turbines. However, the water velocity to a turbine is controlled by a dam and penstock, unlike the wind velocity in the open air.

The sensitivity to wind speed means that in marginal conditions a slight drop in wind can cut power drastically (for example, a drop in wind from 9 to 8 km/h would reduce power by nearly one-third). Where winds are gusty it means that structural resilience and speed control become challenges for wind system designers.

In Ontario, a wind-turbine generating system is being demonstrated at another remote community, Fort Severn, on the shores of Hudson Bay. The wind generator is rated at 150 kilowatts (kW), enough to supply more than 30 houses. It is interconnected to reduce the load on a 200 kW diesel.

Biomass Agricultural

Biomass, a generic term for a variety of organic materials produced with the sun's energy, includes such things as wood (discussed above), municipal waste (discussed below) and agricultural crops. The latter are used commercially as an energy source in many countries. Brazil leads the way with its use of crops to make alcohol fuel for vehicles. The alcohol fuel programs in the United States are making progress slowly, though hampered by low oil prices, in part because support for ethanol production has been linked to agriculture support policies.

Canadian crops and agricultural waste could be converted to ethanol for liquid fuel use, but these technologies are inhibited by low oil prices. At today's energy prices, ethanol from grain cannot compete with gasoline without government subsidies. Technological advances, cheaper feedstocks, and effective use of by-products could help improve the economics of ethanol.

Tidal power

Tidal power, which since the Middle Ages has powered water mills in estuaries flanking the English Channel, was first used for large-scale electric generation in 1967 with installations on the Rance estuary in Brittany (240 MW) and in the USSR. However, a tidal-power dam has significant environmental impacts on its bay or estuary and imposes a large capital cost.

Among the many coastal areas in the world with the required minimum tidal range of 5 metres are the east and west coasts of Canada. The world's highest tides in the Bay of Fundy provide an opportunity for tidal power development and demonstrations. After extensive study the Federal/Provincial Tidal Power Review Board concluded in 1977 that Fundy tidal power could compete on economic terms with electricity from fossil fuels. A 20 MW tidal power demonstration plant at Annapolis Royal in Nova Scotia was completed in 1984, and is operating successfully.

Geothermal technology

Geothermal technologies recover heat from within the earth. In places where earth heat is easily retrieved, such as parts of Iceland, Italy, New Zealand, and the western United States, these technologies are already making a significant and increasing contribution to energy supply. At present there are hundreds of geothermal power plants operating in 17 countries, providing over 5,000 megawatts of power.

Canadian geothermal opportunities exist in the Rocky Mountains, and they might be useful for community heating systems as in Iceland. But the locations are remote from areas of high energy demand, which inhibits their usefulness.

ALTERNATIVE ENERGY

The alternative energy technologies most pertinent to Canada and Ontario are in the areas of transportation fuels, energy from waste, hydrogen, nuclear fusion and peat.

Transportation fuels

The oil crises of the 1970s disclosed the lack of alternatives to crude oil as a source of liquid fuels, which are the basis of transportation. One option is to make crude oil from other hydrocarbon sources. The technologies to make synthetic oil from coal or natural gas are attractive to countries which have a great deal of either. The United States, Canada, and South Africa have done much research and development in this area.

Another approach is to adapt internal combustion engines to consume fuels not usually derived from crude oil. *Propane* and *natural gas* use in vehicle engines are examples. The alcohol fuels, *methanol* and *ethanol*, have also been widely developed as vehicle fuels. They can be blended with gasoline as fuel extenders in conventional engines, or used neat in engines designed for them: in fact methanol is the fuel of choice in racing motors.

In Ontario, propane and natural gas are being widely adopted in automobile and van fleets, supported by tax incentives. There were about 50,000 propane-fuelled vehicles (many of them taxis) and 5,500 natural-gas-fuelled vehicles in Ontario in 1988. Gasoline extended with methanol in a proportion suitable for normal car engines has been marketed by some oil companies. However, methanol has some disadvantages in terms of its fuel properties and corrosion problems, and oil companies currently are leaning to MTBE (methyl tertiary butyl ether) as an automotive fuel component.

A flexible fuel vehicle, able to accept either straight gasoline, neat methanol, ethanol or any combination has been developed and tested with support from the Ontario government. Electric and hydrogen-powered vehicles have been demonstrated in Ontario, but further development is required for their commercial acceptance.

Energy from waste

Energy from municipal waste incineration is becoming popular in industrial countries. Though municipal solid waste has a good heat value, it is not in itself a cost-effective fuel. What makes it attractive is the saving in waste disposal costs, so that the incinerator operator will be paid for, rather than paying for, the fuel used. In many cases, the combination of waste fees plus revenue from steam and electricity sales makes the project feasible to the private developer. In other cases, a municipality chooses incineration for its waste and seeks to recover some of the cost by generating electricity.

In Ontario, energy from the burning of garbage will be an attractive option as municipalities grapple with a problem of waste disposal that is rapidly becoming acute. Energy from waste installations exist at Hamilton and London, and more will be evaluated as municipalities across the province develop master plans for handling their waste disposal.

Other energy from waste possibilities include pyrolysis of old tires, conversion of waste paper to liquid fuels, and methane (natural gas) from the decomposition of garbage in landfill sites. A 23 megawatt cogeneration plant is planned for the Brock West landfill site at Pickering.

Hydrogen

Hydrogen has been suggested as the ultimate fuel of the future, generally within the context of a "Hydrogen Economy". It offers potential as an energy source when fossil fuels become scarce and has the other advantage that it is less damaging to the environment than fuels containing carbon.

Hydrogen is currently being used as a fuel in military and space applications where cost is no object. It may be first used in niche markets such as underground mining vehicles. However, hydrogen is now much too expensive to be used as a fuel in most markets. Any significant use must wait until major cost reductions result from technical breakthroughs in the areas of production and transportation.

Peat

Around the world, beds of peat continue to be used locally for domestic heat and sometimes, as in Ireland and the USSR, for electricity generation. But the sources will not be able to compete generally with bituminous coal as an energy source.

Canada has some of the largest peat beds in the world, but their remoteness from settled areas and the existence of cheaper alternatives make more than peripheral development of peat energy unlikely.

Nuclear fusion

Over the past few decades Canada's nuclear energy efforts have focused on the development and improvement of the Candu nuclear power reactor, which is based on nuclear fission: the splitting of uranium atoms.

For the more distant future Canada and other industrial countries are conducting research

into fusion energy. Fusion is the joining together of light atoms, such as hydrogen, to produce heavier atoms and in the process release large amounts of energy. The goal of the world's fusion research programs is to harness the fusion process to generate energy in the form of heat or electricity. This has not been an easy task and may well be one of the most difficult scientific and engineering challenges ever undertaken. Although steady progress is being made, considerable research effort is still required in such areas as the behaviour of extremely hot gases or plasmas and new heat-resistant materials.

Research efforts around the world now focus on fusion reactors using the principle of magnetic confinement in large doughnut-shaped vessels known as tokamaks. The largest tokamaks operating now are in the UK, the U.S.A., Japan and the U.S.S.R. Canada operates a medium sized research tokomak at Centre Canadien de Fusion Magnetique near Montreal.

In order to rationalize their resources, the world's industrial powers are now collaborating to design and build a prototype fusion reactor to demonstrate the feasibility of fusion power. Canada is participating in this project through the European Community. The Canadian Fusion Fuels Technology Project, which is funded by the federal government, the provincial government and Ontario Hydro, is contributing in areas of Canadian expertise, such as tritium handling systems, remote handling, safety systems and waste management.

Progress towards the commercialization of fusion energy has been technically difficult but steady. Barring any major breakthroughs, commercial fusion power reactors are not expected to appear until after the year 2025.

In 1989, the world's scientific community was astonished by an announcement that fusion seemed to have been achieved in a test tube at room temperature. However, this so-called "cold fusion" phenomenon could not be reproduced in other laboratories around the world and as a result scientists were unable to confirm or accept the scientific principles proposed.

Conservation and Energy Efficiency

AROUND THE WORLD

Energy efficiency has improved greatly in the developed countries since the 1970s. Much further improvement is possible, especially in the countries of highest energy use such as Canada.

Environmental concerns have joined energy costs in motivating energy conservation and efficiency by consumers of all types. Canadians continue to improve the efficiency of their energy use. In Ontario, energy conservation is a high priority, especially to restrain electricity demand growth.

IN CANADA

Since 1973, Canada has reduced its overall energy use per dollar output by 24 per cent, which is approximately the median improvement for advanced economies. But in industrial energy use Canada's improvement has been less than that of other developed countries.

IN ONTARIO

Even with lower oil and natural gas prices the economic and environmental benefits of further energy conservation in Ontario are great. The Ontario government makes improved efficiency its highest energy priority and focuses on removing barriers to development of cost-effective conservation measures.

AROUND THE WORLD

Since the mid-1970s large improvements have occurred in energy efficiency in the industrial nations, whose economic output has grown much faster than their energy consumption. Leading the way was Japan, with a reduction of 37 per cent in energy use per unit of economic output from 1973 to 1986. Canada placed fifth, with a 24 per cent reduction. In these countries the previous close link between the growth of economic activity and the growth of energy consumption was clearly broken during this period. Further improvements in energy efficiency seem likely.

Energy Conservation, Energy Efficiency, and Energy Services

To conserve energy means to limit energy consumption. Conservation has usually been advocated either to save energy because future supplies are in doubt, or to reduce the environmental impacts created by energy consumption, or both. The idea of conservation is to cut back unnecessary energy use.

However, total energy use can continue to grow even with a successful energy conservation policy, because the world's population and economic output is growing. To maintain the benefits of a growing economy while limiting energy use, the aim is to increase energy efficiency. The result is to get more benefits and useful output from any given quantity of input energy.

Basic to the idea of energy efficiency is the concept of energy services. Energy is consumed not for its own sake but to perform identifiable services – heating, cooling, lighting, transportation, motive power, communications, and so on. If a change is made to provide the service another way that uses less energy, energy efficiency is improved and conservation occurs without loss of benefits.

Improvements in energy efficiency can be made by energy consumers in two ways:

- *by acquiring more-energy-efficient technologies (as when a homeowner retrofits a new high-efficiency gas furnace)*
- *by using available technologies more efficiently (as when the homeowner turns down the heating thermostat during an absence from the house).*

In both cases the service benefits are retained with lower energy consumption.

An essential part of this improvement has been played by conservation measures, which have improved the energy efficiency of buildings, vehicles, heating systems, appliances, motors, and other major users of energy. Conservation and the substitution of other fuels for oil have been the main reason for the end of the oil crisis of the last decade. But in part the reduced energy intensity also reflects the relative growth of service sectors of the economy, whose energy consumption per dollar of output is much lower than that of industrial sectors, and the relative decline of the most energy-intensive industries.

Energy prices have had a lot to do with conservation. Higher prices in the 1970s and early 1980s not only encouraged consumers to become conscious of energy efficiency in purchasing and using equipment but also spurred industry to develop and market more energy-efficient technologies. Since 1986 energy prices have softened and are less of a driving force for

conservation. But another factor has begun to have a similar effect.

The new push for conservation arises from concerns about *environmental impact* and sustainable forms of economic development. The production and use of energy has major impacts on the environment and therefore is a focus of these concerns. The environmental impacts of concern include the following:

- The impacts of global warming (the greenhouse effect), the largest single cause of which is the production of carbon dioxide from burning fossil fuels. The 1988 International Conference on the Changing Atmosphere recommended that governments seek ways to reduce global carbon dioxide emissions to 80 per cent of 1988 levels by the year 2005.
- The impacts of toxic and acidic air emissions from hydrocarbon combustion (including low-level ozone, acid rain, etc.).
- Radioactive emissions associated with the nuclear fuel cycle in electricity generation.
- The impacts of flooding for hydroelectric megaprojects.
- The massive increase in global energy consumption and environmental effects that would result if Third World industrialization followed the traditional pattern.

In the developed countries consumers and governments impelled by these concerns have begun to emphasize the need for restraining the growth of energy consumption with new patterns of behavior and with much more energy-efficient technologies.

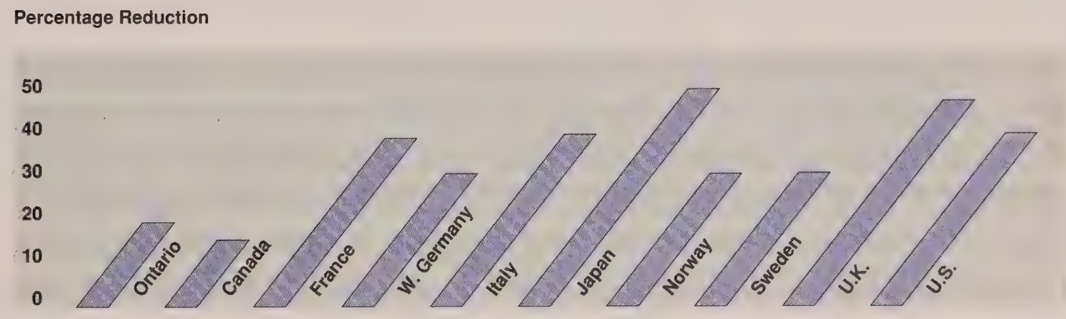
The International Energy Agency (IEA) continues to encourage industrialized countries to adopt policies promoting energy efficiency, and estimates that a further improvement of 30 per cent could be achieved by the year 2000.

IN CANADA

As noted in the introductory chapter, comparative statistics from the International Energy Agency show Canada to be the highest energy user among industrial countries in relation to economic output. Canada's great dependence on energy is often attributed to a cold climate, the long distances, the high standard of living, and the preponderance of energy-intensive industries such as aluminum smelting, pulp and paper, and petrochemicals.

REDUCTIONS IN INDUSTRIAL ENERGY USE PER DOLLAR OUTPUT IN SELECTED COUNTRIES, 1973-86

Some developed countries have made greater reductions than others in industrial energy intensity.

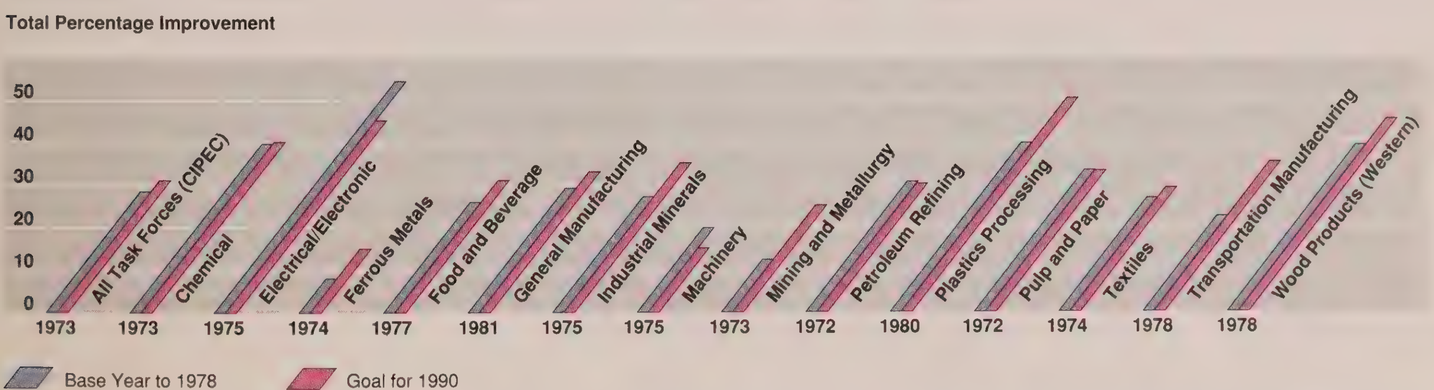


Canada's reduction of 24 per cent in overall energy use per dollar of GDP from 1973 to 1986 occurred despite a much smaller reduction in the industrial sector. When industrial energy use per dollar of GDP is considered, Canada's 16 per cent improvement was only half that of the next lowest (Norway and West Germany, 32 per cent) and less than one-third that of the leader, Japan (52 per cent).

The improvements recorded in Canada are in part due to the efforts of the Canadian Industrial Program for Energy Conservation (CIPEC), in which 14 industry task forces share

ENERGY CONSERVATION BY INDUSTRY IN CANADA TO 1987

Task forces in 14 Canadian industries have made good progress towards their energy-efficiency goals.



information on energy conservation techniques. According to CIPEC (using a different measure of energy use from the IEA, combined with certain adjustments), from 1973 to 1987 across all task forces the decrease in energy use per physical unit of output averaged 28 per cent. The electrical/electronics, chemicals, and plastics processing industries showed the greatest gains.

During much of this period Canadian government policy encouraged energy efficiency. For instance, under the Canadian Home Insulation Program (CHIP) from 1977 to 1987, grants amounting to nearly $1 billion assisted in the insulation of 3 million housing units.

Since 1984 federal priorities have moved towards deregulation and increased reliance on market forces. Program spending has been greatly reduced. The CHIP program has been ended. Under the Energy Efficiency and Diversity Initiative announced in 1988, federal programs now emphasize research and development and information activities. However, business investments in certain energy-saving technologies or applications are encouraged through accelerated capital depreciation in the tax system.

The R-2000 home program encourages energy conservation through quality, energy-efficient home building. R-2000 homes have more insulation, tighter construction and more efficient ventilation and heating and cooling systems than regular homes. Space heating requirements of an R-2000 home are approximately 30% of a comparable modern home.

Technological Change and Energy Efficiency

Energy efficiency in developed countries is expected to continue to improve as more efficient use is made not only of energy directly but also of materials which require energy to make.

The manufacture of bulk materials – pulp and paper, industrial chemicals, petroleum products, glass, cement and clay products, and metals – has been estimated to be five to ten times more energy-intensive than the rest of manufacturing. The production and use of these materials has been declining in North America, relative to all manufacturing, since the mid-1970s. Lighter materials, improved product durability, and saturating markets for heavy goods have all contributed to this change.

The trend will be accentuated by the increasing costs of waste disposal and concerns about the environmental impact of waste, which will promote recycling, reuse, and recovery of materials. The Ontario government, for example, recently announced a target of diverting 50 per cent of the waste sent to disposal in 1987 to recycling, reuse, and recovery by the year 2000. These processes are usually much more energy-efficient than the extraction of new raw materials.

Here are some examples of more energy-efficient technologies likely to become more common in Canada:

- *New heating technologies: high-efficiency natural gas furnaces, heat pumps, and industrial microwave process heating.*
- *New industrial processes: fluidized bed combustion, thermomechanical pulping, oxygen furnaces in steel smelting, membrane technologies.*
- *Automated control systems: computerized energy management systems, automated industrial process controls, electronic fuel injection in engines.*

IN ONTARIO

In Ontario the benefits of energy conservation are of two main kinds: economic and environmental. Sometimes it is cheaper to meet an expected increase in energy consumption by making corresponding reductions in consumption elsewhere than by building or purchasing new production facilities. It therefore makes economic sense to invest in all conservation measures that are more cost-effective than new resource options. Furthermore, reducing energy consumption while maintaining the level of energy services would improve the environment. Cleaner air and water, fewer risks and concerns about electricity generation, fewer transmission lines, pipelines, and distribution systems are benefits of significant value throughout the province.

Ontario government policy on energy efficiency
The Ontario government promotes cost-effective and efficient use of energy resources on the following principles:

- *Remove barriers to acceptance*: The government addresses removing barriers to commercialization such as lack of information or technical expertise, market-entry difficulties for new technologies, regulatory obstacles, and lack of capital. Through information, education, financial assistance, regulation and other measures, the government will seek to improve the ways in which Ontarians use energy.
- *Encourage long-lasting structural improvements:* Investments in many large energy uses last a long time: industrial equipment and processes, homes and commercial buildings, vehicles, and appliances. New capital and equipment being designed and installed should incorporate a high standard of energy efficiency.
- *Support for research and development:* Many recent innovations in energy-efficient technology have resulted from government-assisted research and development. The govern-

ment supports the development of new technologies and energy-efficient processes, from research and design stages through to full-scale demonstration trials, as appropriate.

- *Encourage diversity in energy sources:* The province's energy security can be improved by encouraging a diversity of competing energy supplies. The transportation sector, in particular relies almost exclusively on petroleum products.

In support of these policies the Ontario government has implemented a number of programs and initiatives:

- Energy information is distributed in a variety of publications and media, in conferences and seminars, in technical training materials for architects, engineers, builders, and tradesmen.
- Policy direction has been given to Ontario Hydro that conservation and efficiency are the first priority in meeting future electricity needs.
- Financial assistance is available in selected areas to help energy users overcome barriers to conservation. Support is also given to new energy-efficient technologies and processes from research and design through commercialization.
- Minimum levels of energy efficiency for appliances and other products are being introduced under the new Energy Efficiency Act. Regulatory barriers to the adoption of energy-efficient technologies and practices are being reviewed.
- Proposed revisions to the Ontario Building Code call for higher levels of insulation in new housing.
- Measures are being examined to make the government vehicle fleet and buildings more efficient.

Electricity Conservation

To meet the province's future electricity needs, Ontario Hydro will look to conservation and efficiency before considering large new generation options.

In response to the government's directive, in June 1988 Ontario Hydro announced a target which would reduce the forecast growth of peak electricity demand by 3000 MW by the year 2000. Of this total, 2000 MW would be achieved by improvements in electricity efficiency stimulated by incentives to customers. Another 1000 MW would be achieved by shifting electricity use from periods of peak demand to off-peak periods when surplus production capacity is available. In addition Hydro has identified 1500 MW of conservation which are included in the forecast of slowing electricity demand growth, and will be aided by information and advice programs.

To achieve this total 4500 MW target, Ontario Hydro is introducing a wide range of electricity efficiency and demand management programs. Over the next six years this will cost about $1.2 billion, and will involve the co-operation and participation of municipal utilities, equipment suppliers, and others in the electricity industry, as well as electricity consumers. Incentives and advice will be offered for R-2000 homes, water-heater blankets, high-efficiency lighting, heat pumps, energy-efficient building design, high-efficiency industrial motors, energy monitoring and control systems, efficient industrial processes, and others.

The technical potential for electricity conservation is even higher than these targets. A study for the Ministry estimated 6600 MW of electricity conservation potential exists by the year 2000. However, this assumed 100 per cent adoption of all the identified conservation measures.

Industrial sector

Ontario industries – manufacturing, mining, agriculture, forestry, and construction – consume about 36 per cent of the province's end-use energy. About two-thirds of industrial energy is used to generate heat for production processes, with the remainder divided mainly between lighting, electrochemical processes, space heating and motive power.

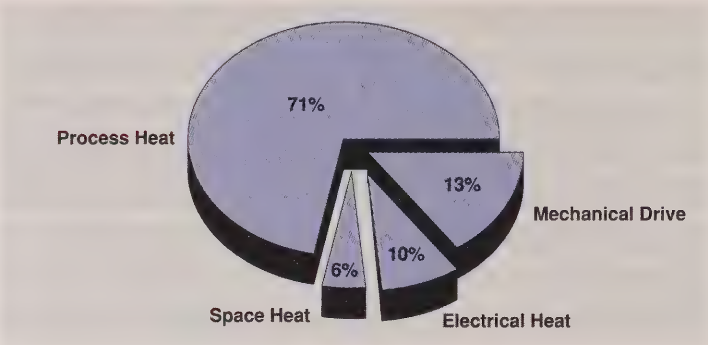
For Ontario industry the energy price increases in the 1970s and early 1980s were dramatic. For example, from 1971 to 1985 the price to industrial users of fuel oil grew by ten times, of natural gas by eight times, and of electricity by four times. The result was an industrial drive for energy efficiency. Substantial gains in energy efficiency per dollar output have been made mostly since 1979, especially in the major energy-intensive industries.

Several Ontario government programs are helping to realize the potential for energy efficiency in industry. Under the Industrial Energy Services Program 195 comprehensive energy analyses have been done up to March 1989, with the following results:

- 864 energy efficiency improvement projects have been identified. A total capital investment of $48 million could save $25 million annually in energy costs, for an average simple payback period of only 1.9 years.
- On average, savings amount to 7 per cent of electricity costs and 11 per cent of fuel costs.
- About half of these projects have been or seem likely to be implemented.

The Energy Monitoring Demonstration Program provides equipment to pinpoint and monitor energy consumption levels throughout a plant, revealing costs and waste. The Process Equipment Demonstration Program offsets some of the risks of implementing new energy-

efficient process technology and waste heat recovery technology in industrial applications. The Agriculture Energy Services Program encourages investment by farmers in proven, commercially available energy-efficient technologies through site analysis and information, assistance to demonstration projects, and financial assistance for specific technologies.



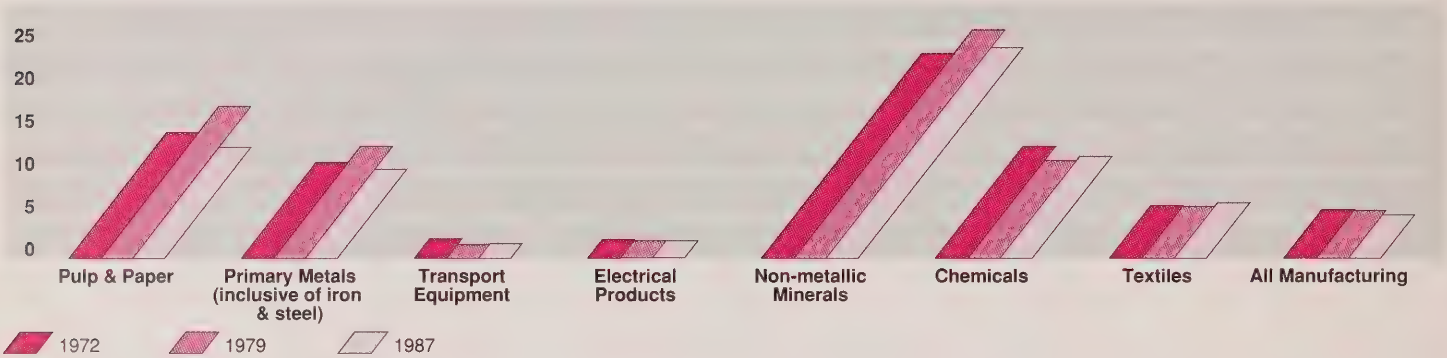
USE OF ENERGY IN CANADIAN INDUSTRY IN 1987

More than half the energy consumed by industries in Canada is used for heat in processing, while over one-tenth is used for mechanical drive and transportation.

Source: CIPEC, 1987 (Energy Mines & Resources)

ENERGY CONSUMPTION PER DOLLAR OF OUTPUT IN SELECTED ONTARIO INDUSTRIES, 1972-87

Between industries there are large differences in energy intensity and in the amount of improvement in energy efficiency.



Residential sector

Residential energy use accounts for about 19 per cent of total end use energy in Ontario. The biggest residential energy use is for space heating (two-thirds), with the remainder divided more or less equally between water heating and appliances, including lighting. Natural gas supplies about one-half of residential energy, electricity nearly one-third, and oil about one-seventh.

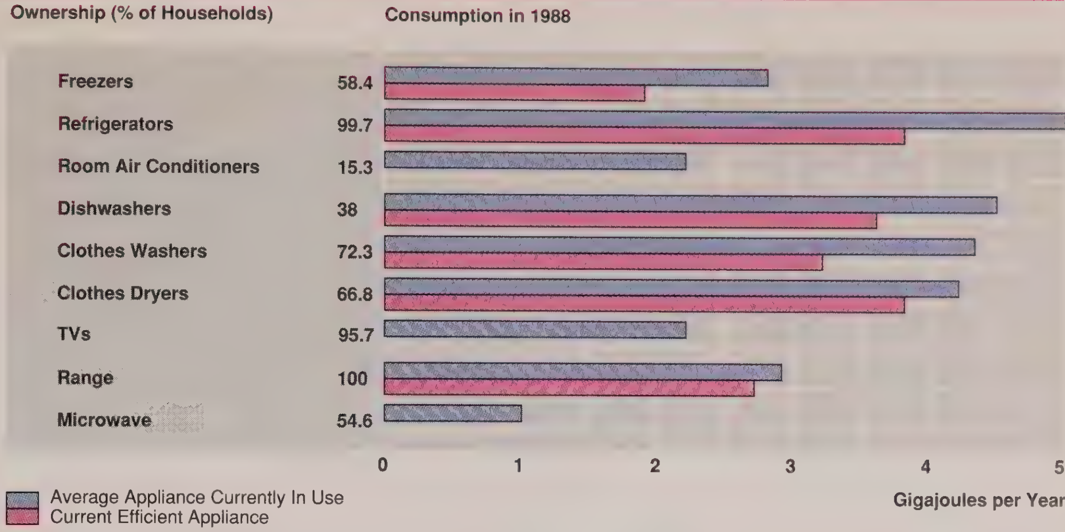
Energy use per housing unit in Ontario has dropped since 1970 by 30 per cent. The main reason for the decline was consumer conservation, as homeowners retrofitted older homes (insulation, draft-proofing, improved windows and doors), installed more-efficient heating systems, purchased more efficient appliances, and adopted energy-conscious behaviour. A second reason was a shift to smaller, more energy-efficient homes, although this trend has recently reversed. With Ontario residential consumers still spending more than $4 billion on household energy bills, a large potential for further conservation remains.

To realize this potential the Ontario government undertakes initiatives for residential energy users, such as consumer information programs, workshops for people selling energy-related products, efficiency advice for service trades, open houses to demonstrate R-2000 homes, and energy-efficient design contests for students of design and architecture.

Design improvements have made many new household appliances more energy efficient. For example, an average refrigerator built in 1987 uses up to 25% less energy than the average model then in use. The average 1987 air conditioner is 20% more efficient. However, some consumers do not purchase the most efficient new appliance possible, even though the resulting energy savings more than offset the higher purchase price over the lifetime of the appliance.

The Energy Efficiency Act, 1988, a major Ontario government initiative, creates a framework for energy efficiency regulations for appliances, heating, cooling, and other equipment. Equipment sold or leased in Ontario after specific dates will have to meet performance standards, a requirement that could improve energy efficiency by 15 to 30 per cent. The government is also working to include cost-effective energy-efficiency measures in the Ontario Building Code for standard residential construction.

High-efficiency furnaces are an important means of lowering household energy consumption. At present about one-third of the new gas furnaces being installed are high-or mid-efficiency units, with seasonal efficiencies over 80%. The most efficient condensing gas furnaces are over 90% efficient, and use only two-thirds the amount of gas of a standard furnace.



OWNERSHIP AND AVERAGE ENERGY USE OF MAJOR APPLIANCES IN ONTARIO IN 1988

Though use patterns vary widely, there are significant differences in average energy use by appliance.

Commercial and institutional sector

This sector provides services to the Ontario economy in facilities such as municipal street lighting and in a wide variety of buildings ranging from corner convenience stores to shopping malls, from low-rise warehouses to office towers, from hockey arenas to schools, hospitals, and nursing homes. Altogether this sector accounts for about 13 per cent of Ontario's end-use energy consumption. Rising energy costs after 1973 made energy conservation attractive to building owners and operators. Since that time, energy consumption has grown at less than one-third the rate of economic output in the service sector.

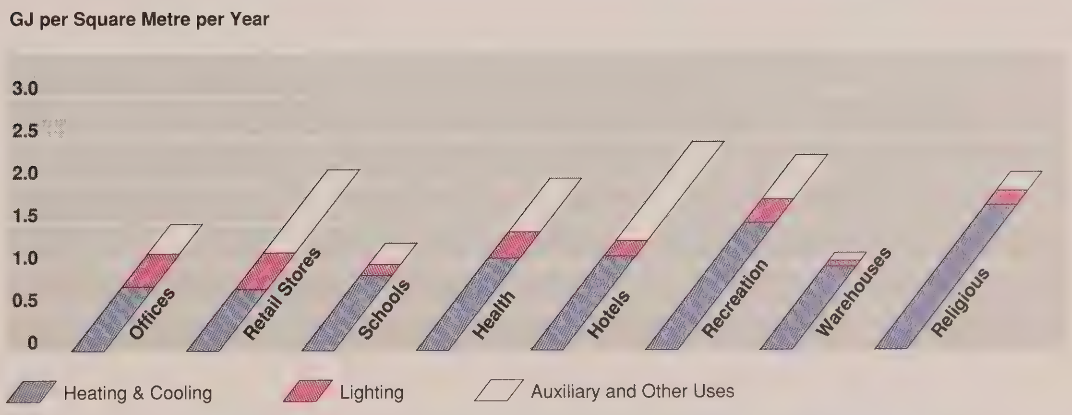
Space heating and cooling account for two-thirds of total energy use in the sector, water heating and equipment operation for about one-fifth, and lighting for the rest. But there are large variations that depend on the kind of building. Hospitals and schools use more energy than average for space heating, while offices and stores use more energy than average for equipment and lighting.

Different building uses also represent different potentials for conservation. Efficient lighting systems offer a large potential for conservation in many buildings, and this can also help reduce cooling requirements as the heat produced by the lighting is reduced. Computerized energy management and control systems, which manage a building's total energy-using systems, have proved very successful.

Many older buildings in use today, built when energy was cheap and plentiful, are energy-inefficient in design, though their owners and operators have often been able to reduce energy costs significantly by simple measures such as careful control of temperatures and lighting. Many new buildings are designed to use as little as one-quarter as much energy as buildings constructed just 10 years ago.

The Ontario government has been encouraging energy conservation in the commercial and institutional sector. It continues to encourage energy conservation through its support for the Municipal Building Energy Efficiency Program. Programs provide information, financial assistance, support for technology demonstration and training for building managers and operators.

The Ontario government's Downtown Energy Forum, which began in Toronto in 1978, has successfully brought an exchange of ideas on a voluntary basis between owners, managers, and operators of buildings through seminars, workshops, and other meetings. The concept was extended in 1983 to Ottawa and in 1987 to Oshawa, Niagara Falls, London, and Sudbury. By 1990, the Cities Energy Forum will be available in 18 medium-sized municipalities across Ontario.



ENERGY USE IN THE AVERAGE COMMERCIAL AND INSTITUTIONAL BUILDING IN ONTARIO, 1987

The intensity of energy use differs between building types.

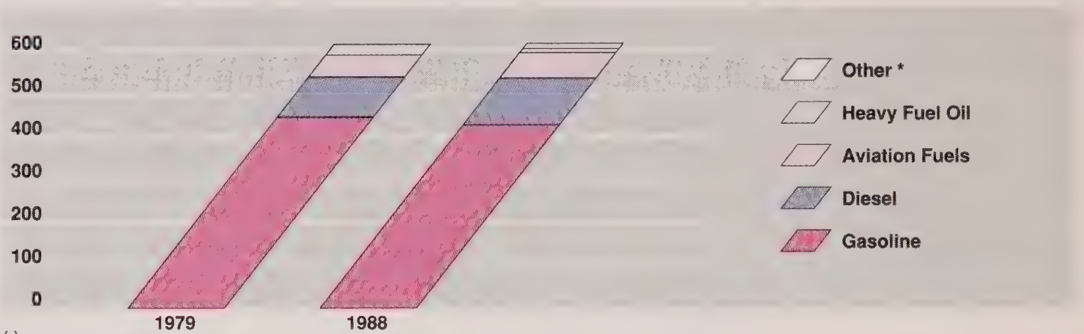
Transportation sector

Automobiles, trucks, airplanes, ships and trains use the second-largest amount of energy in Ontario after the industrial sector. Moreover, the energy used – 24 per cent of total end-use energy – is almost entirely based on crude oil.

Transportation energy consumption, having peaked in 1979 and dropped in the early 1980s, is now growing again but more slowly than before. Consumption in 1988 was essentially the same as in 1979, despite 0.9 million more automobiles and more trucks and aircraft. Gasoline accounts for more than two-thirds of total use, followed by diesel fuel and aviation fuel.

TRANSPORTATION FUEL CONSUMPTION FOR ONTARIO 1979-1988

The drop in gasoline consumption because of greater automobile fuel efficiency has offset the consumption increases in other fuels.



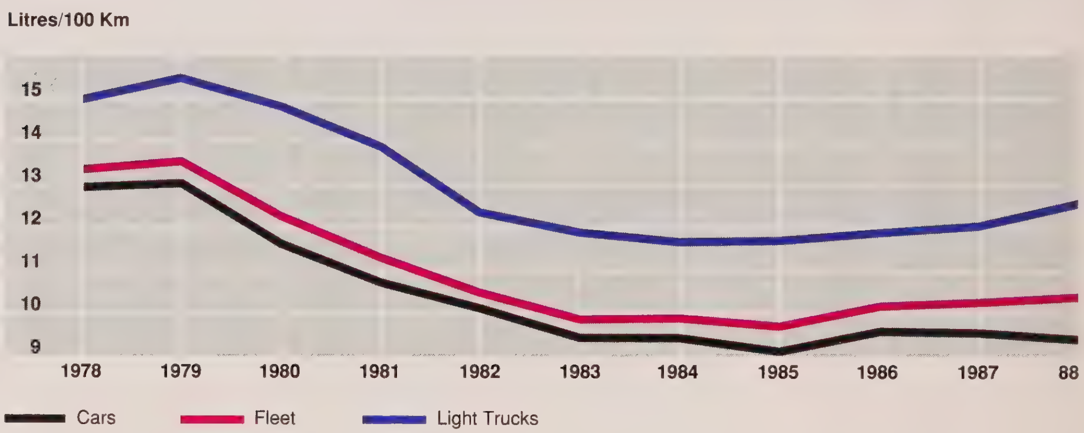
(*)
1979, includes only electricity
1988, includes natural gas, propane and electricity.

In the last 15 years automobiles have become smaller and more fuel-efficient. Ontario roads hold more four-cylinder engines and fewer eight-cylinder engines; the average new car weight has dropped by more than one-third; and fuel economy has improved by more than one-quarter. However, further gains may be slower: lower oil prices have removed consumer incentives to buy smaller cars, and the least costly design improvements have now been made. Also, car buyers are purchasing more vans and light trucks which are less fuel-efficient than passenger cars.

ONTARIO'S NEW VEHICLE FUEL EFFICIENCY, 1978-1988

Through design downsizing and consumer purchase decisions, the average new vehicle became much more energy-efficient in the 1980s.

Note: Fuel efficiency refers to the average fuel efficiency of new vehicles purchased in each year.



Diesel fuel's share of transportation fuel use has nearly doubled since the early 1970s. The main reason is that a greater proportion of freight is now shipped over long distances by truck, rather than by rail or ship, because of the convenience of delivery to the door. The extra-heavy duty diesel trucks which are used for this purpose are now 14 per cent more efficient than in 1980. However, the rapid growth in their number may offset some of the efficiency gains made through the use of radial tires and radiator fans, improvements to engine intake and reduction in aerodynamic drag. This brings higher fuel use per tonne-kilometre of freight moved.

Since 1980, aviation fuels demand has increased by 16 per cent, as demand for air travel has increased. However, fuel saving measures such as route rationalization and technical improvements in engine and body design have increased fuel efficiency of airplanes. For instance, since 1984 fuel use per seat-kilometer has declined about 5 per cent.

Energy Outlook

Over the next sixteen years in Ontario energy use is expected to grow more slowly than economic output as energy efficiency improves. Industrial use of energy will expand significantly, and the shift away from oil to natural gas and electricity will continue. Electricity demand growth will be moderated by incentives for increased electrical efficiency.

A RANGE OF FORECASTS

How will the energy supply and demand picture in Ontario change over the next sixteen years? Forecasters must estimate probable changes in such factors as oil prices, inflation rates, economic growth, and technological development, all of which will affect Ontario's energy needs.

Since a great many uncertainties are involved, a range of forecasts, or "outlook scenarios", is generated, based on differing sets of assumptions about trends among determining factors. This range of forecasts centres on a "most-likely" or "reference" case.

The Ministry's most recent forecasts of Ontario's energy needs to the year 2005 have produced three outlook scenarios:

- The *reference outlook,* regarded as the most likely of the three, assumes moderate growth of the Ontario economy (3.1 per cent a year from 1988 to 2000, and 2.8 per cent from 2000 to 2005), population growing to 11.35 million, and only a small increase in the real cost of oil (an oil price averaging US$20-22 in constant (1988) dollars from 1993 onwards).
- The *low-demand outlook* assumes slower annual economic growth (2.4 per cent), 3 per cent fewer people than in the reference case, and higher oil and natural gas costs (real oil price of US$24-26 from 1993).
- The *high-demand outlook,* compared to the reference outlook, assumes faster annual economic growth (3.4 per cent to 2005), faster population growth, with the same oil and natural gas costs.

For each outlook the forecasters project the energy efficiency and fuel choice decisions made by the major users in every economic sector. This is used to forecast the end-use demand for energy in all areas of the provincial economy in each case.

All three scenarios share the following general assumptions:

- *Population.* Ontario's population growth will continue to slow down through the 1990s, dropping below 1 per cent a year by 2000 in the reference outlook.
- *Economic structure.* Goods-producing industries, such as autos, steel, and chemicals, will grow more strongly than service industries, such as financial services, travel, health care, and the government sector.
- *Technological change.* There will be no major new uses of energy on the scale of the automobile or the airplane, but new technologies will have significant effects on energy use in all sectors of the economy. The new technologies will tend to be more energy-efficient than the ones they gradually replace.
- *Energy prices.* Energy prices will change but will not experience major shocks on the scale of those of 1973-4 and 1979-80. The world price of oil will strongly influence the prices of natural gas and coal and thus drive demand for energy generally.
- *Energy markets.* The Free Trade Agreement is gradually implemented. Energy trade increases, export controls are reduced, and prices are increasingly influenced by continental market forces.

- *Energy efficiency.* Energy conservation and efficiency will steadily improve in Ontario with government encouragement. Ontario Hydro will introduce large-scale incentive programs to improve electricity efficiency and slow demand growth (with impacts discussed separately below).
- *Renewable energy.* Renewable sources other than water-power and wood will make only a small contribution to supplying Ontario's total energy needs.

From 1988 to 2005 Ministry forecasts predict that Ontario energy consumption will grow more slowly than economic output. Industrial consumption and electricity grow most rapidly, while oil continues to decline in relative importance.

HIGHLIGHTS OF THE MINISTRY'S 1989 "MOST-LIKELY" REFERENCE FORECAST, 1988 – 2005

	1988	2005	Growth (%)
Key economic variables			
Population (million)	9.4	11.4	21
Total real GDP (million of constant 1971 dollars)	$60,196	$99,389	65
– goods	$23,512	$41,916	78
– services and government	$36,684	$57,473	57
Automobile registrations (million)	4.6	6.5	41
Households (million)	3.5	4.8	37
Commercial floorspace (million sq. meters)	186	288	55
Energy variables (Petajoules)			
Total end-use energy	2576	3555	38
Sectoral end-use			
– industrial (including non-energy use)	1138	1743	53
– transportation	619	804	30
– residential	485	554	14
– commercial	334	454	36
Fuel end-use			
– oil	982	1235	26
– natural gas	776	1076	39
– natural gas liquids	61	85	39
– coal (industrial)	205	323	58
– electricity	462	716	55
– wood and other	90	120	33

END-USE ENERGY CONSUMPTION BY ECONOMIC SECTOR

Total

Having increased strongly in the 1970s, Ontario energy consumption flattened out in the 1980s, so that the total in 1988 was only slightly above that in 1980. The forecasts predict a resumption in the growth of consumption, but at a moderate pace. The forecast total increase 1988-2005 in the reference case is 38 per cent (averaging 1.9 per cent annually), with a range from 23 per cent in the low-demand case to 53 per cent in the high-demand case.

Energy use in all three scenarios grows more slowly than the economy as a whole, owing to substantial improvements in energy efficiency. In the reference case, energy use grows at two-thirds the rate of the economy. With higher energy prices in the low-demand case, the greater is this efficiency improvement.

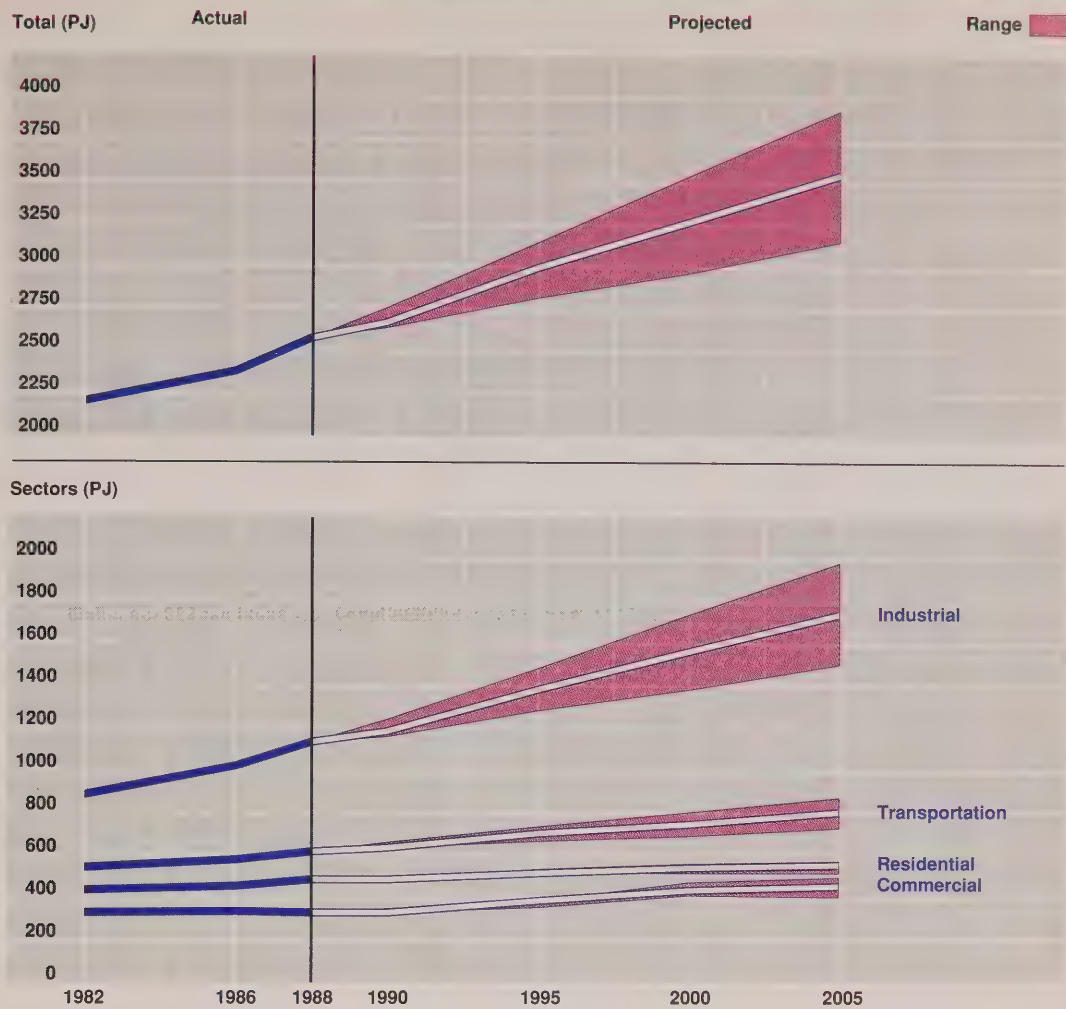
The response of energy use to economic pressures differs between sectors. For example, residential energy use is slower to react to economic conditions and energy prices, since housing stock lasts a long time and changes its composition slowly. But transportation energy use reacts more quickly because motorists can adjust the distances they drive and most passenger cars are replaced within ten years.

From 1988 to 2005 in the reference outlook, the 38 per cent increase in end-use energy consumption is unevenly distributed between sectors. The heaviest increase is the industrial sector's 53 per cent (including non-energy uses such as petrochemicals). Residential consumption increases least at 14 per cent, while commercial consumption (36 per cent) and transportation consumption (30 per cent) are between the extremes. The industrial sector is also the most sensitive to the differences between the three outlook scenarios, while the residential sector is the least affected.

A clearer view of the expected growth of end-use energy demand in Ontario can be gained by examining the reference outlook scenario for the four sectors individually. This outlook excludes the effect of Ontario Hydro's electricity efficiency programs, which is discussed separately.

END-USE ENERGY CONSUMPTION BY SECTOR IN ONTARIO, 1988-2005

All sectors except residential are expected to use more energy, with the strongest growth occurring in the industrial sector.



Industrial sector

Total industrial energy demand grows at 2.5 per cent a year from 1988 to 2005, or 53 per cent in total, in the reference outlook. There are interesting differences in demand growth for different fuels. Demand growth for natural gas and natural gas liquids (55 per cent) and for coal (58 per cent) are close to the overall demand growth. Oil lags (40 per cent), as does "other" energy use (39 per cent), while electricity surges ahead (70 per cent).

Improvements in energy efficiency throughout industry will restrain demand by reducing energy use per unit of output. At the same time, output from several large energy-intensive industries – e.g. iron and steel, industrial chemicals – is expected to grow more quickly than average, having the opposite effect. The result of these two offsetting trends is expected to be only a small overall improvement in industrial energy intensity.

The following factors exercise important influences on industrial energy consumption:

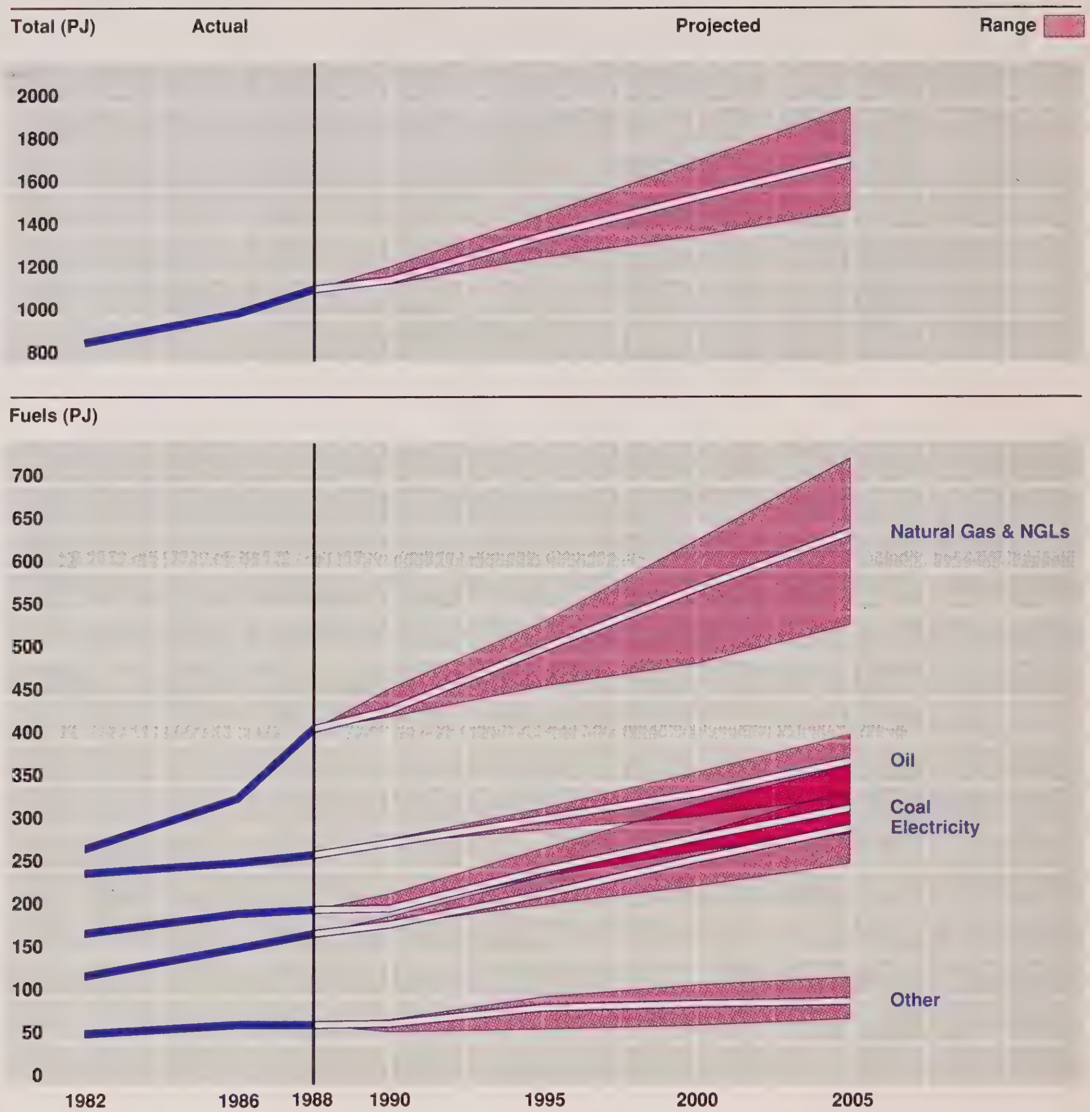
- *Three large industries.* The iron and steel, pulp and paper, and industrial chemicals industries accounted for 60 per cent of industrial sector energy consumption in 1988. Developments in these industries have the greatest weight in affecting future consumption.
- *Pace of technological change.* Improved energy efficiency will arise from the introduction of basic oxygen furnaces and continuous casting in iron and steel, thermomechanical pulping in pulp and paper, and automated process controls in industrial chemicals. However, shifts in production technology will also affect fuel choices. For example, although thermomechanical pulping is more energy efficient on a total energy basis, it is electricity-intensive. Similarly, new technology in plasma arc melting and inductive electric furnaces increases the demand for electricity while decreasing coal and fuel oil use.
- *Investment in new capacity.* Substantial investment in new capacity is expected in many industries, to meet growing demand, improve product quality and respond to the challenge of international competition. As new, more energy-efficient capacity is added the per unit energy consumption should improve.
- *Mix of primary and secondary industries.* Primary industry, based on raw material extraction and processing, is much more energy intensive – a recent estimate suggests ten

times more – than secondary manufacturing. Within an industry the mix of products is also important. In pulp and paper, the more finished product, paper, requires further energy to produce on top of that needed for the raw material, wood pulp.

- *Environmental improvement.* Many industries are investing heavily to reduce emissions to the environment, in order to meet regulations concerning water and effluent quality, acid gas and particulate emissions, etc. Often the new investments improve overall energy efficiency, but are electricity-intensive. In the mining and smelting of primary metals, for example, the use of oxygen in smelting and automated equipment underground will increase electricity use.

INDUSTRIAL END-USE ENERGY CONSUMPTION IN ONTARIO, 1988-2005

The strong growth forecast in industrial energy use will be based mainly on natural gas and coal, while oil consumption grows more slowly.



Transportation sector

Total transportation energy use grows by 30 per cent from 1988-2005 in the reference outlook. Unlike the other sectors, transportation consumes almost entirely oil products (98 per cent), a situation that will not change substantially by 2005 in this outlook. Total transportation energy consumption will be especially sensitive to the price of oil. It is anticipated that 57 per cent more diesel, 43 per cent more aviation fuels and 21 per cent more gasoline will be used by 2005.

Diesel accounts for more than 17 per cent of energy used in the transportation sector, largely in the shipment of freight by road, rail, and ship. The shift away from bulk freight (predominantly carried by rail and ship) toward more finished goods shipments (mostly carried by road) is expected to continue. Also, rationalization of railway facilities, urbanization, and the convenience of trucking enhances the growth of road transport. Since road transport uses more energy per tonne of freight moved than either rail or marine, all these factors causing the shift to trucking help to boost the demand for diesel fuel.

Gasoline accounts for almost 70 per cent of energy consumption of the transportation sector. The majority of gasoline use is for passenger travel, but business and service use are important too. Gasoline use is expected to grow slowly between now and 2005, with much of the

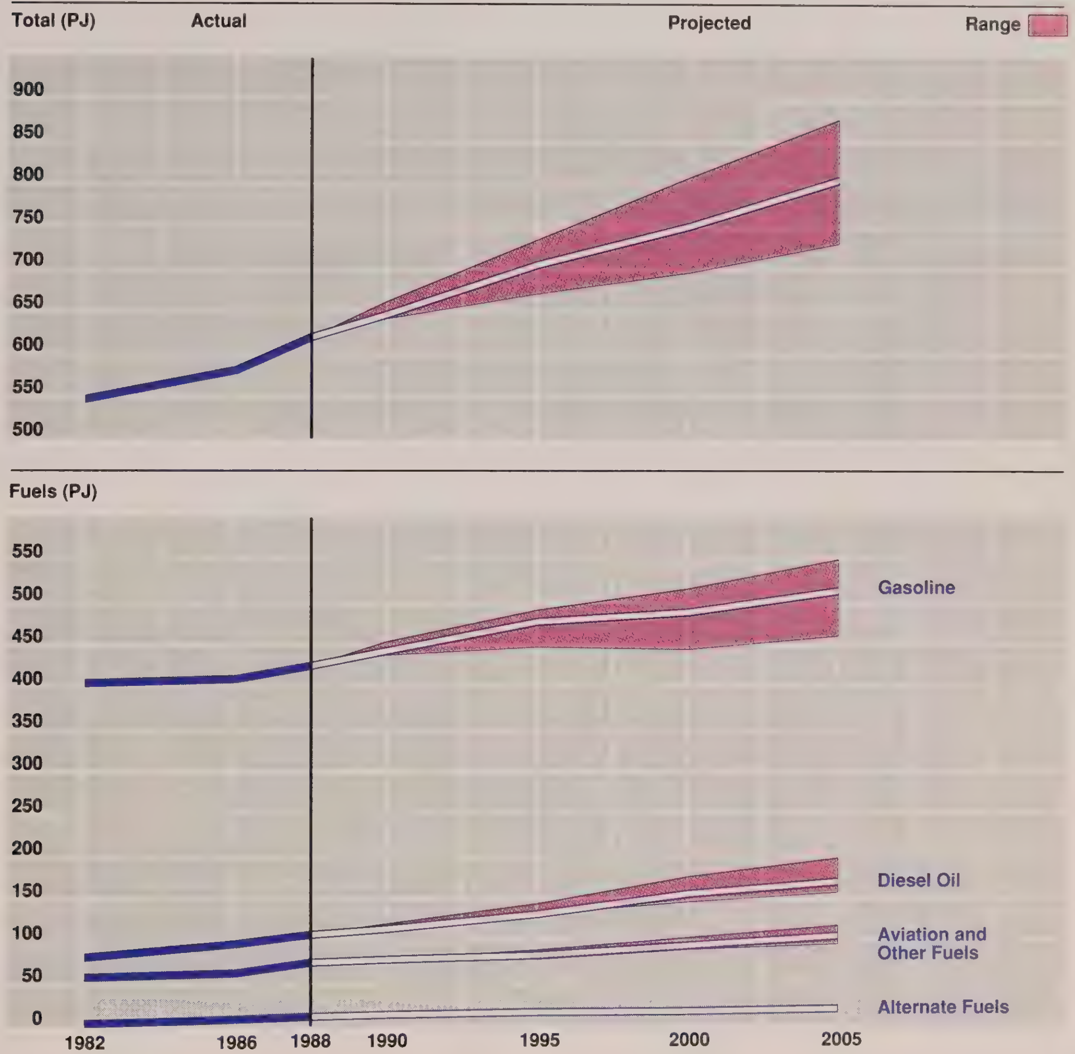
growth occurring in the near term. An aging population and a more fuel-efficient vehicle stock are responsible for this slow growth. The fuel economy of passenger cars will continue to improve but more slowly than in recent years. Since 1979, the average passenger car in the total fleet has decreased in weight and become more fuel efficient as new cars have replaced older models. In spite of the growing popularity of light trucks, vans and performance cars in the last few years, it is anticipated that the trend towards more fuel efficient vehicles will continue. Higher real oil prices, increased fuel taxes and environmental concerns are the main reasons underlying this continued trend.

Aviation fuels account for just under one-tenth of the energy used by the transportation sector. Rising personal disposable incomes and more leisure time are the main reasons that aviation fuel consumption is expected to grow at just over 2 per cent a year.

Advances in alternative transportation fuels are also forecast: natural gas and propane grow by 62 per cent and electricity by 46 per cent, while methanol and ethanol are expected to increase their use in blends with gasoline. Natural gas use could expand to 5.3 PJ, with a projected 50,000 natural gas vehicles on the road by 2005. Propane use grows more modestly, to 12.4 PJ. Alcohol fuels (methanol and ethanol) are not expected to make major inroads, but could account for 2.6 PJ.

TRANSPORTATION END-USE ENERGY CONSUMPTION IN ONTARIO, 1988-2005

The dominance of gasoline as a transportation fuel remains unaffected in the forecasts.



Residential sector

From 1988 to 2005 in the reference outlook, residential energy consumption increases by only 14 per cent overall, the smallest increase among the sectors. In the same period the housing stock is expected to increase by about twice as much or about 82,000 new homes annually until 2000, and 65,000 per year, thereafter. This implies an impressive increase in energy efficiency.

Although total residential consumption increases, use by fuel varies greatly. Natural gas and liquids, the largest fuel category, grows slightly less (12 per cent) than overall consumption, as householders retrofit older gas-heated homes, new homes become more energy-efficient, and the share of high-efficiency gas furnaces increases. By 2005, it is expected that the average gas furnace efficiency in single family homes will rise from the current 70 per cent to 76 per cent.

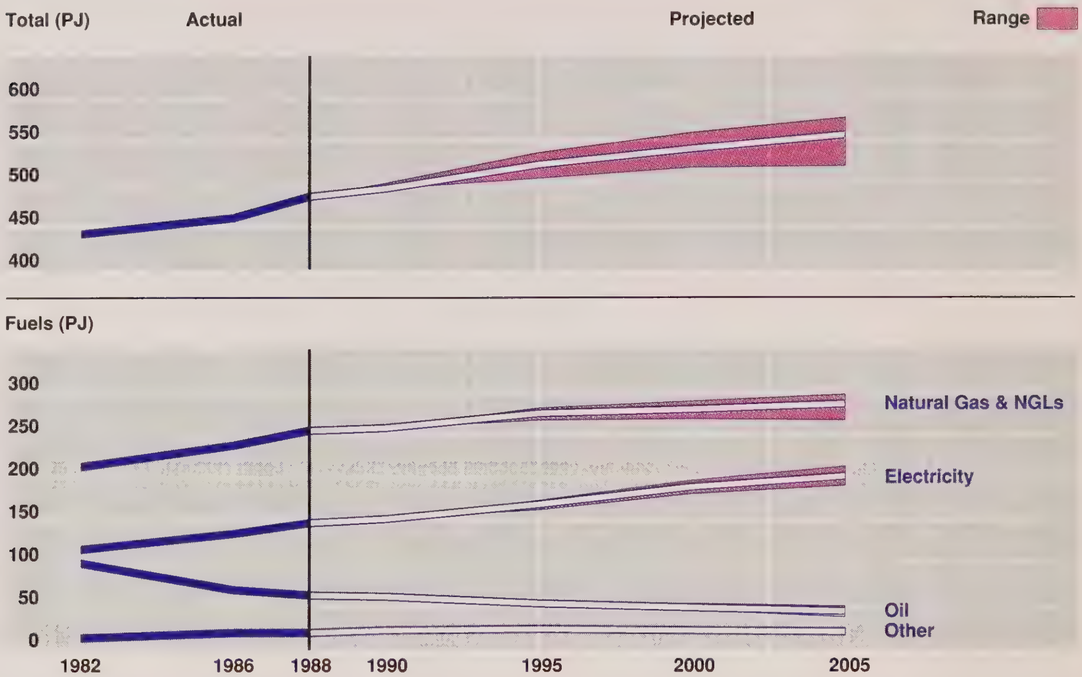
Also by this date, an average single family gas-heated home will require 12 per cent less energy than is currently required for space heating. Oil consumption falls in absolute terms by 29 per cent, as oil furnaces continue to be replaced by natural gas and electricity. The biggest increase is in electricity consumption (37 per cent), particularly for space heating and appliance use.

By 2005, space heating will remain the largest end-use of energy but is expected to decline slightly in importance (to 63 per cent), while appliances' share will increase (to 12 per cent). Water heating's share will remain unchanged at 16 per cent, while space cooling will double in absolute terms, but still account for less than 1 per cent of total consumption.

Changes in this pattern will result from changes in the number, type, and size of homes; from more energy-efficient heating equipment and appliances, influenced by the Energy Efficiency Act regulations; and from trends in the lifestyle behaviour of occupants.

RESIDENTIAL END-USE ENERGY CONSUMPTION IN ONTARIO 1988-2005

Electricity Consumption is expected to grow during the 1990s in the residential market, while oil use continues to fall.



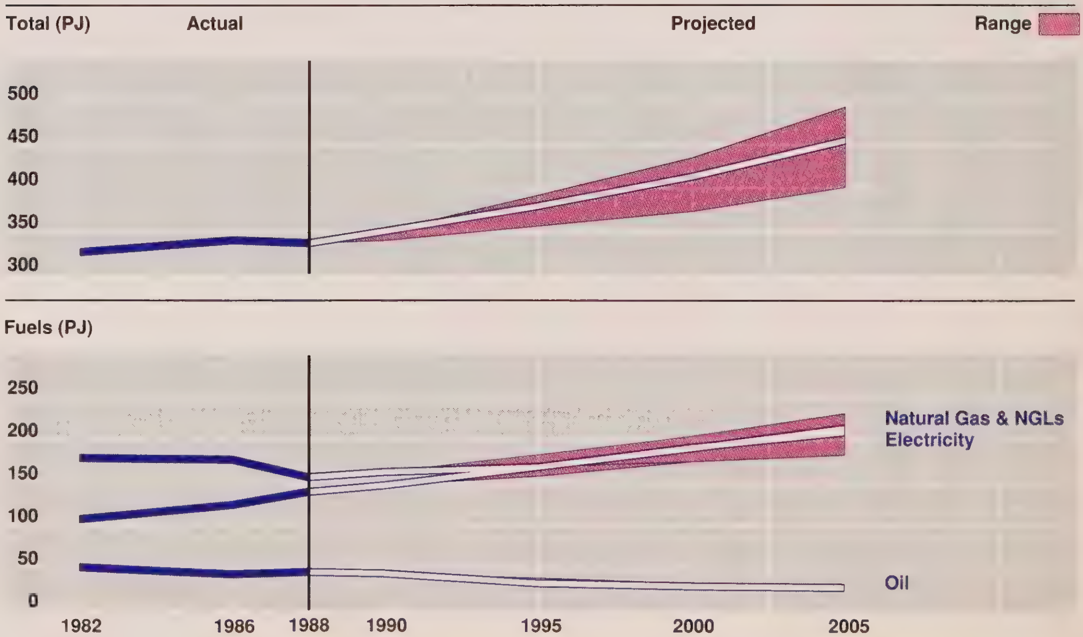
Commercial sector

From 1988 to 2005 in the reference outlook, commercial/institutional energy consumption increases strongly by 36 per cent. Natural gas, the largest fuel use in the sector, is expected to show the same increase. However, electricity shows very strong growth (55 per cent) to overtake natural gas as the leading fuel by 2005. On the other hand, oil consumption falls absolutely by 28 per cent, as remaining oil use in heating buildings is phased out.

The commercial/institutional sector supplies services. It does so mainly in a wide variety

COMMERCIAL/INSTITUTIONAL END-USE ENERGY CONSUMPTION IN ONTARIO, 1988-2005

In the commercial and institutional markets energy use will grow significantly, while natural gas and electricity will continue to displace oil.



of large buildings which use energy for heating, cooling, lighting, and internal equipment. Consumption depends not only on the total floor space but also on the differing characteristics of the various services provided. Increased electricity use is a feature in most of these buildings, reflecting increasing demand for electrical equipment and growing roles for electrical space heating.

Auxiliary equipment, including computers, copiers and other electrical equipment, is expected to have the highest growth rate of all the end-uses of energy in the commercial and institutional sector. From 1988 to 2000, energy to power auxiliary equipment is expected to increase by 2.4 per cent a year, declining marginally to 2.1 per cent after 2000.

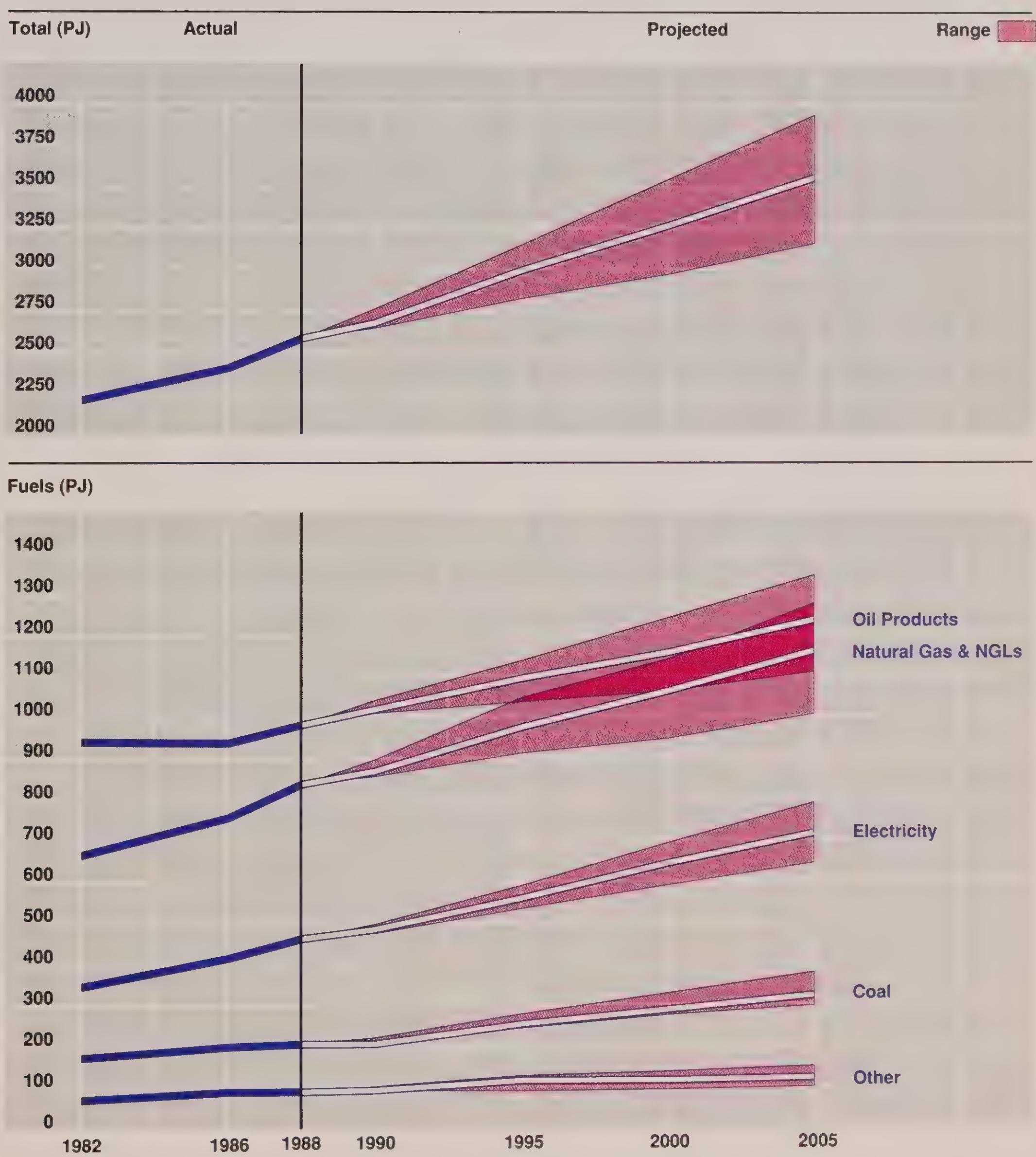
The improvement in energy efficiency in the commercial/ institutional sector is expected to be about 0.8 per cent a year, comparable to that in the residential sector. But the expected increase in commercial building stock is a substantial 2.6 per cent a year, so that energy consumption in the sector is forecast to increase by more than twice as much as in the residential sector.

END-USE ENERGY CONSUMPTION BY FUEL

When these sectoral demand trends are put together, electricity and coal grow more quickly, natural gas and natural gas liquids at the average rate, while oil declines in relative importance.

END-USE ENERGY CONSUMPTION BY FUEL IN ONTARIO, 1988-2005

Natural gas use grows at the average rate, electricity and coal grow more quickly, while oil lags and declines.



Oil

From 1988 to 2005 in the reference outlook oil consumption increases by one-quarter. The main use continues to be transportation (62 per cent in 1988 and 63 per cent in 2005), followed by

industry (27 rising to 30 per cent because of growth in non-energy uses). Oil use in the residential sector dwindles from 7 to 4 per cent of total oil use and in the commercial sector from 4 to 2 per cent.

Natural gas

From 1988 to 2005 in the reference outlook natural gas end-use consumption grows by 39 per cent. Having made inroads in the residential sector in the past decade, natural gas will now see the industrial and commercial sectors begin to catch up. Industrial use rises from 50 per cent of total natural gas consumption in 1988 to 55 per cent in 2005. Commercial use holds its own at 18 per cent, while residential use falls from 31 to 25 per cent of total use because of improved furnace efficiencies and house construction. Transportation consumption grows slightly from 1 to 2 per cent of natural gas end-use demand.

Coal

From 1988 to 2005 strong growth in the iron and steel industry is expected to cause coal consumption to go up by 58 per cent. (Coal for electricity generation is not included in this figure.)

Electricity

In the reference outlook electricity demand grows by 55 per cent from 1988 to 2005, prior to considering the effect of Ontario Hydro's incentive programs. With the continuing introduction of higher-technology electricity-based processes, industrial use surges ahead, increasing its share from 38 per cent of electricity demand in 1988 to 42 per cent in 2005. Commercial use keeps pace to hold its present 30 per cent share. Residential use grows more slowly and its share falls from 32 to 28 per cent. Transportation consumption also grows but remains less than 1 per cent of total electricity consumption.

The effect of Ontario Hydro's incentive programs for electricity efficiency and load shifting, assuming the targets are achieved, would be to reduce the forecast peak electricity demand growth by one-third by the year 2000. If similar savings continue to be achieved, the reference outlook growth of peak demand could be reduced to 36 per cent up to 2005, a growth rate of under 2 per cent a year.

Other energy forms

"Other" energy consumption consists largely of the burning of wood waste and spent pulping liquor by the pulp and paper industry, and wood used for home heating, plus some methanol used as a transportation fuel. In the reference outlook, "other" energy consumption increases from 1988 to 2005 by 36 per cent. Growth is above average in the industrial sector, rising from 71 PJ in 1988 to 91 PJ in 2005, and in the transportation sector, with consumption growing from negligible to about 2.6 PJ. Growth in the residential sector lags as wood heating does not grow substantially.

PROSPECTS FOR SUPPLY

By the year 2005, Ontario will probably consume more than it did in 1988 of every kind of energy: 26 per cent more oil, 58 per cent more coal, 39 per cent more natural gas, and 55 per cent more electricity (before demand management). And this, the most likely case, assumes improvements in conservation and energy efficiency. How much of this energy will come from within the province? From within Canada? How much will Canada depend on external sources of energy?

Oil

Production from established conventional oil reserves in Western Canada is expected to decline significantly over the next twenty years as existing fields are depleted. Part of the decline will be offset by new discoveries in the conventional areas and the introduction of improved oil extraction methods. However, for more valuable light oil Canada may increasingly need to rely on costly new sources, such as the frontier regions of the East Coast offshore and the Beaufort Sea, and the oil sands of Alberta. The alternative is to become more dependent on foreign countries for oil.

Because of Canada's limited remaining conventional supplies, its future as a major oil producer depends on when its frontier and oil sands reserves are developed. Canada's two largest frontier oil fields are Amauligak in the Beaufort Sea, with 525-650 million barrels of oil, and Hibernia off the coast of Newfoundland, with 525 million barrels. Even more impressive are Alberta's oil sands, which the Alberta Energy Resources Conservation Board believes contain 290 billion recoverable barrels of bitumen. Bitumen already accounts for about 300,000 barrels a day, or roughly 20 per cent of total Canadian oil production.

Development of new supplies will be very sensitive to expectations about future oil prices. According to 1988 National Energy Board forecasts, if oil prices remain low there will be no new megaprojects and only a small amount of frontier oil production. In that case Canada's crude oil

productive capacity falls by 28 per cent from 1987 to 2005, mainly because of a decline in light oil capacity. If oil prices are high, the Board forecasts some frontier production and some upgrading of heavy oil and bitumen into synthetic oil, though this will only slow down the long-term decline in light oil capacity. With high oil prices the Board sees Canada remaining a net oil exporter overall at least until 2005.

With low oil prices the decline in Canadian supply would mean that Ontario increasingly will rely on non-Canadian sources of light oil. The Board forecasts such imports rising from 3 per cent of provincial light oil requirements in 1995 to 6 per cent by 2000 and to 30 per cent by 2005. By contrast, if oil prices are high, encouraging new Canadian supply, Ontario's light oil imports would hold at 3 to 4 per cent through 2005, according to the Board.

Natural gas

The National Energy Board estimated Canadian established reserves of natural gas at the beginning of 1988 to be about 90 exajoules (EJ), equivalent to 85 trillion cubic feet (Tcf).

The Board has become more optimistic about Canadian natural gas reserves. Its estimate of total ultimately available economic reserves rose from 176 Tcf in 1986 to 195 Tcf in 1988. The estimated additions to reserves by 2005 are also substantially higher: 49 Tcf with high prices and 44 Tcf with low prices (up from 16 Tcf and 32 Tcf in 1986). The main reasons cited by the Board for these changes are higher expected gas prices, lower finding and production costs in some cases, and a higher estimate of technically recoverable reserves.

The current surplus of supply in the natural gas market should be eliminated by 1994, after which a rough balance of supply and demand is foreseen through 2005. Total Canadian natural gas productive capacity, about 4.4 Tcf in 1987 is forecast to change little, falling slightly to 4.3 Tcf if prices are low and rising to 4.8 Tcf if prices are high. In both cases, Mackenzie Delta gas comes into production in 1999; other frontier sources begin producing in 2004 in the high-price case.

Natural gas exports are forecast to average 1.4 Tcf a year, in both price scenarios. The levelling of exports forecast by the Board is attributed to slow growth in US gas demand and adequate US domestic gas supply. However, other forecasters see exports rising to around 2.0 Tcf by the end of the century.

Coal

Remaining Canadian economically recoverable coal reserves are estimated by the National Energy Board to be 6578 megatonnes, or more than 100 years of production at current rates. The Board forecasts strong increases in Canadian coal production. From the 1987 level of 61 megatonnes, with low energy prices coal production increases by 2005 to 77 megatonnes and with high energy prices to 102 megatonnes, a two-thirds increase.

In view of the vast known reserves in Western Canada, coal is a secure Canadian energy source. Transportation costs in future are expected to drop because of technological improvements. However, the future use of coal will be affected by environmental concerns, particularly over acid gas emissions affecting air quality and carbon dioxide emissions affecting global warming, and will thus depend also on technological developments to make coal combustion more environmentally benign.

Electricity

In the Ministry's reference outlook, peak generating capacity needs would increase by 9000 megawatts in 2000, and a further 3600 MW by 2005, before considering the effects of incentives for electrical efficiency. The Darlington nuclear station will provide 3500 MW of this need by 1992.

To meet these increased needs, two options are being given priority by the Ontario government. The first priority is strategic electricity conservation and efficiency, that is, slower demand growth by means of special incentives to customers. Ontario Hydro currently plans to achieve a reduction of 2000 MW in peak power needs by the year 2000 through energy-efficiency incentive programs, and another 1000 MW from shifting electrical loads off-peak (together termed demand management).

The second priority of the Ontario government is increased parallel generation, that is, power generation by the private sector, usually industry or entrepreneurs. Much of this could appear as industrial cogeneration. The government believes that at least 2000 MW of new parallel generation can be brought on by the year 2000.

However, demand management and parallel generation will not eliminate the need to increase electricity supply. Ontario Hydro's 1988 plans call for 1100 MW of additional hydro-electric capacity, as explained in the Electricity chapter. The Ministry's forecast indicates that additional options beyond those already planned will be needed around the year 2000 assuming demand grows as in the reference forecast. If demand grows faster, then new measures will be needed sooner.

The most likely supply options are hydroelectric, nuclear, coal-fired and natural gas-fired generation, and electricity purchases from outside Ontario. Each of these options has certain limitations. Much of the remaining undeveloped hydroelectric capacity in Ontario is limited in

size or accessibility. The environmental concerns about coal combustion have been discussed earlier in this review. The price of natural gas is a concern for gas-fired generation. Nuclear generation, though proven as a safe and economical supply source and supported by ample indigenous resources of uranium, is the object of public concern over safety and waste disposal. Large electricity purchases from sources outside the province such as Quebec Hydro raise questions of cost and security of supply.

Ontario Hydro's plans for meeting future electrical requirements, to be announced late in 1989, will recommend choices from among these options and will be considered with full public review under the Environmental Assessment Act.

Conclusion

In the years up to 2005, energy planners expect a period of stable and consistent growth of energy consumption in Ontario based on moderate world oil prices.

Oil consumption will grow slowly. Though oil will decline further in relative importance, it will remain the overwhelming basis of transportation. Natural gas consumption will grow moderately, while electricity consumption will grow more strongly, although restrained to some extent by efficiency incentives and programs.

However, in all sectors continuing improvements in energy efficiency and conservation will enable economic activity to grow faster than energy use and will bring a continuing decline in energy consumption per unit of economic output.

In the near future at least, the four most important energy questions to watch in Ontario will be:

- the effectiveness of programs and incentives for energy conservation and efficiency
- the choice of new supply options to meet Ontario's growing electrical demand
- the impact of growing North American energy demand on Canada's energy exports
- the influence of environmental concerns and measures to reduce environmental impacts of energy supply and use.

Statistical Appendix

NOTE ON SOURCES

The statistics in the Ontario Energy Review are for the most part derived from the Statistics Canada surveys and consequently become available only gradually. Generally the most up to date information is incorporated in this Review. However, some of the latest figures have had to be estimated.

Statistics Canada, the Department of Energy, Mines and Resources, the National Energy Board, Ontario Hydro and the International Energy Agency (IEA) statistical publications were among the main data sources utilized for this review.

ENERGY CONVERSION FACTORS

Standard Measure of Energy Content

1 **joule (J)** is the energy required to raise the temperature of 1 gram of water by 1 degree centigrade.

1 **gigajoule (GJ)**, is one billion joules, and is a measure appropriate for the individual consumer. One GJ of gasoline is about 29 litres, or one half of a tankful.

1 **petajoule (PJ)** is one million GJ, and is a measure appropriate for the province. One PJ of gasoline would fuel 14,500 cars for a year assuming each car uses 2,000 litres. Also, one PJ of electricity would serve the needs of 22,000 single family homes for a year (space heating excluded).

Energy

1 joule	(J)	=	0.000948 BTU (British Thermal Units)
kilojoule	($kJ = 10^3 J$)	=	thousand joules
megajoule	($MJ = 10^6 J$)	=	million joules
gigajoule	($GJ = 10^9 J$)	=	billion joules
terajoule	($TJ = 10^{12} J$)	=	trillion joules
petajoule	($PJ = 10^{15} J$)	=	quadrillion joules
exajoule	($EJ = 10^{18} J$)	=	quintillion joules

HEAT VALUE EQUIVALENCE

Energy Form	Heat Value
Crude Oil	
Light and Medium	38.51 GJ/m^3
Heavy	40.90 GJ/m^3
1 cubic metre (m^3) = 1,000 litres = 6.293 barrels	
Natural Gas	
(at 15°C, 101.325 kilopascals and free of water vapour)	
Alberta (domestic)	38.80 MJ/m^3
East of Alberta	37.65 MJ/m^3
1 cubic metre (m^3) = 35.301 cubic feet	
Liquified Petroleum Gases (LPGs)	
Liquified Petroleum Gas	27.10 GJ/m^3
Ethane (liquid)	18.36 GJ/m^3
Propane (liquid)	25.53 GJ/m^3
Butane (liquid)	28.62 GJ/m^3
Coal	
Bituminous	27.60 GJ/tonne
Subbituminous	18.80 GJ/tonne
Lignite	14.40 GJ/tonne
Average domestic use	22.20 GJ/tonne
1 tonne = 1,000 kilograms = 1.102 short tons	
Petroleum Products	
Motor gasoline	34.66 GJ/m^3
Aviation gasoline	33.52 GJ/m^3
Aviation turbo fuel	35.93 GJ/m^3
Diesel & light fuel oil	38.68 GJ/m^3
Heavy fuel oil	41.73 GJ/m^3
Other products	39.82 GJ/m^3
Coke	28.83 GJ/tonne
Coke Oven Gas	18.61 MJ/m^3
Electricity (*)	3.6 MJ/kW.h

(*)This conversion factor is the heat value of electricity and is used for secondary energy calculations (eg. comparison of different home heating fuels). For primary energy calculations the conversion factor (10.5 MJ/kilowatt hour) is adopted for hydraulic and nuclear electricity; this is the equivalent thermal energy, assuming the efficiency of conversion is that of a coal-burning plant.

Other

1 cubic metre (1000 litres) = 219.969 Imperial gallons = 264.172 American gallons
1 kilogram = 2.20462 pounds
1 metre = 3.281 feet
1 kilometre = 0.621 miles

Table 1: Ontario's Energy Consumption by Sector and by Fuel Type, 1988

	(Petajoules)								
End-Use Energy	**Oil**	**Natural Gas**	**Natural Gas Liquids**	**Electricity**	**Coal**	**Hydro**	**Nuclear**	**Other[5]**	**Total**
Secondary:									
– Residential	62	241	11	147		—	—	19	**480**
– Commercial	42	149	3	139		—	—		**333**
– Industrial[1]	96	379	6	177	205	—	—	71	**935**
– Transportation	607	0.5	10	1.3		—	—		**619**
Total Secondary	807	770	30	464	205	—	—	90	**2,367**
Non-Energy Uses:									
– Petrochemicals	112	0	32	0	0	—	—	0	**144**
– Other	59	0	0	0	0	—	—	0	**59**
Total End-Use	**978**	**770**	**62**	**464**	**205**	—	—	**90**	**2,570**
Primary Energy									
Own Uses & Losses[2]	87	60		41	0	0	0	0	**188**
Electricity – Generation[4]	8	9	0		347	382	705	1	**1,451**
– Less: Net Exports[3]					(25)				**(25)**
Steam Generation							19		**19**
Less: Electricity	—	—	—	(505)	—	—	—	—	**(505)**
Total Primary	**1,073**	**839**	**62**	**(0)**	**527**	**382**	**724**	**91**	**3,697**
Primary Fuel Shares (%)	29	23	2	—	14	10	20	2	**100**

Notes:

(1) Industrial use includes agricultural consumption and steam generation but excludes petroleum refining which is included in own uses and losses.
(2) Own uses and losses includes energy used by the energy industries and conversion losses.
(3) Electricity exports are assumed to be generated by coal.
(4) Electricity is a secondary energy form, generated by primary fuels shown here.
(5) Other is largely wood use in residential heating and pulp and paper industry.
Source: *Ministry of Energy estimates based on Statistics Canada, 57-003.*

Table 2: Ontario's Crude Oil Supply By Source, 1988

Source	Petajoules	Million Cubic Metres
Ontario	7	191
Manitoba	5	136
Saskatchewan	103	2,666
Alberta	861	22,363
Northwest Territories	21	550
Imports	31	795
Total	**1,028**	**26,701**

Table 3: Ontario's Natural Gas Supply By Source, 1988

Source	Petajoules	Billion Cubic Metres
Ontario	29	0.8
Saskatchewan	69	1.8
Alberta	730	19.4
Imports	14	0.4
Total	**842**	**22.4**

Table 4: Ontario's Coal Supply By Source, 1988

Source	Petajoules	Million Tonnes
Saskatchewan	32	2.2
Alberta	51	1.8
British Columbia	23	0.8
Imports	464	16.8
Total	**570**	**21.6**

Table 5: Ontario's Energy Expenditures By Fuel Type, 1988

	Millions of Dollars
Oil	3,405
Natural Gas and Liquids	2,512
Coal	419
Electricity	6,104
Total	**12,440**

Notes:
Based on wholesale energy prices (crude oil purchased by refineries, natural gas at the city gate, electricity as sold by Ontario Hydro); and primary consumption of crude oil and natural gas; end-use consumption of coal and electricity.

Source:
Ministry of Energy Estimates

Table 6: Canadian Oil Supply and Demand Projections, 1987-2005

LOW PRICE CASE (Million Cubic Metres)											
	SUPPLY							DEMAND			
	Domestic					Imports	Total Supply	Exports		Refineries' Use	Total Demand
Year	Light	Synthetic	Frontier	Heavy	Total			Light	Heavy		
1987	64.8	10.4	0.1	22.8	98.1	23.6	**121.7**	15.1	19.1	87.6	**121.7**
1990	58.8	14.3	0.0	22.9	96.0	27.7	**123.7**	12.8	22.3	88.7	**123.7**
1995	45.2	18.2	0.0	17.1	80.6	28.2	**108.8**	5.2	13.7	89.9	**108.8**
2000	36.6	18.3	3.7	15.6	74.1	31.6	**105.7**	2.6	12.5	90.7	**105.7**
2005	31.3	18.3	4.7	16.7	71.0	37.2	**108.2**	2.6	14.2	91.4	**108.2**

HIGH PRICE CASE (Million Cubic Metres)											
	SUPPLY							DEMAND			
	Domestic					Imports	Total Supply	Exports		Refineries' Use	Total Demand
Year	Light	Synthetic	Frontier	Heavy	Total			Light	Heavy		
1987	64.8	10.4	0.1	22.8	98.1	23.6	**121.7**	15.1	19.1	87.6	**121.7**
1990	62.3	14.3	0.7	28.3	105.6	27.8	**133.5**	15.4	28.9	89.2	**133.5**
1995	51.8	18.3	5.7	35.3	111.0	22.8	**133.8**	5.4	38.2	90.3	**133.8**
2000	40.8	26.7	17.9	33.1	118.6	18.6	**137.1**	9.9	35.7	91.5	**137.1**
2005	33.8	32.9	17.9	32.9	117.5	18.5	**136.0**	7.9	35.8	92.3	**136.0**

Source: *National Energy Board: Canadian Energy Supply and Demand 1987-2005, September 1988, pp.360-362, 368-369*

Table 7: Canadian Natural Gas Supply & Demand Projections, 1987-2005

LOW PRICE CASE (Billion Cubic Metres)

	DEMAND			ADJUSTED PRODUCTIVE CAPACITY
Year	Domestic	Exports	Total	
1987	58	27	85	118
1990	63	37	100	114
1995	71	39	110	116
2000	77	39	116	122
2005	82	39	121	122

HIGH PRICE CASE (Billion Cubic Metres)

	DEMAND			ADJUSTED PRODUCTIVE CAPACITY
Year	Domestic	Exports	Total	
1987	58	27	85	118
1990	68	37	105	115
1995	81	39	120	126
2000	87	39	126	130
2005	91	39	130	134

Source: *National Energy Board, Canadian Energy Supply & Demand 1987-2005 Sept. 1988, p.329-330.*

Notes: *Adjusted productive capacity refers to capacity adjusted to reflect that quantities produced equal total primary demand.*

ISSN 0226-9392

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